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CLIMATE CHANGE IMPACTS ON SERBIAN AGRICULTURE

REPORT ON OBSERVED CLIMATE CHANGE IMPACTS ON AGRICULTURE IN SERBIA AND FUTURE PROJECTIONS OF CLIMATE IMPACTS BASED ON DIFFERENT SCENARIOS REGARDING FUTURE EMISSIONS

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CLIMATE CHANGE IMPACTS ON SERBIAN AGRICULTURE

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TABLE OF CONTENTS

1.
AGRICULTURE
IN GENERAL

Agriculture is a very important activity in Serbia, with a share of 6-6.8% in the gross national income (GNI) in the period 2015-2017, together with forestry and fishery [P.1]. Primary agriculture is mainly based on small family farms (a total of 631,552 farms with 1,442,628 workers), which represent around 20% of the population, with only 12% engaged in additional activities, such as food processing or rural tourism. Average size of agricultural property is only 5.4 ha, divided into, on average, 6 separate lots. Average lot size is around 1 ha [P.2]. Such an unfavourable property structure increases the vulnerability of agriculture and can hinder its development.

In 2018, total size of used land was 3,438,130 ha. Plant production is more dominant in the total value of agricultural production (61.7%) compared to livestock production (38.3%). In the period 2015-2017, the most common forms of land were ploughlands and gardens (75.9%), followed by meadows and pastures (18%), fruit orchards (5.4%), vineyards (0.6%) and other (0.1%). Relative to the 2012 Agricultural Census, there has been an increase in the size ploughlands, gardens and fruit orchards at the expense of meadows and pastures. Agricultural production is present in all parts of the country and on all terrains. Field crop and vegetable production dominate in flatland areas, while fruit production is represented somewhat more in mountainous areas, in addition to field crop and vegetable production.

Plant production – The most common agricultural products are maize, wheat, sunflower and soybean, and the most common vegetables include potato, pepper and beans.

Fruits predominantly include plum, apple, raspberry and sour cherry production, taking up around 75% of areas under fruits, whereas other fruits take up the remaining 25% of areas. Fruit production has recorded growth, both in the size of areas covered and the volume of production, especially when it comes to the production of apples, pears, raspberries and apricots, which is the result of the introduction of climate adaptation measures, such as irrigation and/or hail nets.

Livestock production – Present on all terrains, predominantly in mountainous areas. Poultry production is dominant, with numbers going above 16.6 million, followed by pigs with over 3 million, then sheep and cattle breeding. It should be noted that the volume of livestock production has decreased in terms of the number of poultry, goats, horses and pigs, and has remained at almost the same level in terms of the number of cattle, horses and sheep relative to the 2012 Agriculture Census. Presented by livestock units, a decrease of around 9% has been recorded. A rise has only been recorded in the number of beehives (by around 22%).

Organic production has increased from 218 to 6,154 farms in the period between 2011 and 2017. Total arable land under organic production is 7,540 ha, and another 5,919 ha are in the process of transferring to organic production. According to the most recent data [P.3], total organic production covers 19,200 ha. Livestock numbers in organic cattle production have dropped from 283 to 87, while there is a stable number of sheep (4,665), goats (248) and poultry (4,415).

2. CLIMATE CHANGE AND AGRICULTURE

2.1. Observed climate change with potential impacts on agriculture

Agriculture is particularly vulnerable to climate change, considering that this production is like "a factory under the sky". In agriculture, plant production (field crops, vegetable, fruit and vine production) is particularly under threat, but also livestock production and fishery, and, by extension, food production. Irregularities in the raw material supply chain for food industry lead to economic and social precarity.

Climate in Serbia largely depends on the terrain, altitude, large water areas (lakes) and other conditions. Data from weather stations record significant climate change in Serbia. Perceived climate change trends, based on perceived climate parameters in the period 1961-2017 and 1998-2017 may present numerous negative effects, although some positive effects on agriculture can also be expected.

Based on possible future emissions of greenhouse gases (GHGs), climate indexes projections for the rest of the century have been made. Two selected scenarios deemed probable for our country, RCP4.5 and RCP8.5, will lead to an increase in temperature by at least 0.6°C in the near future, and up to possibly even 4.3°C by the end of the century. Seasonal changes show that summer and autumn will observe slightly greater changes than spring and winter. The projections for total annual precipitation do not show clear trends. Changes are in the range of ±5%, with positive values on the northern part of the territory and negative on the south, which will more or less remain so until the end of the century. In the analysis of change in seasonal precipitation, the reduction of precipitation during the summer season is evident under both scenarios, with a more pronounced anomaly in the far future of up to -20 %. The duration of the drought period will not change significantly, by a few days, but there will be an increase in the number of tropical days and waves. Projections for changes in the increase of precipitation sum with over 20mm, 30mm and 40mm indicate an increase of 20%, but also 30% in Vojvodina and 40% in some parts of South-East Serbia by the end of the century. An extension of the vegetation period of 10 days can be expected in the near future, up to 50 days by the end of century, and even 70 days at higher altitudes in South-West Serbia[1].

All above-mentioned projections for climate indices show that it is necessary to monitor changes, review the risks and continuously adjust adaptation measures, such as agro-technical and other measures, in order to ensure stable and successful agricultural production.

2.2. Analysis of risks and effects of climate related disasters on agriculture

Analysis by sectors

Natural disasters in **field crop and vegetable production** have effects on plant stress, aggravated agro-environmental conditions for the production and inability to apply adequate agricultural practices and technologies. When certain climate factors vary by not reaching or exceeding optimal plant needs, plant stress occurs and yield and quality of products decrease. The most significant negative effects of natural disasters are presented in Table 1.

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[1] More information about observed climate changes and future projections can be found in the Observed Climate Change in Serbia http://www.klimatskepromene.rs/wp-content/uploads/2019/04/Osmotrene-promene-klime-Final_compressed.pdf

Table 1: Effects of climate related disasters in crop and vegetable production

Plant stress	Aggravated agro-environmental conditions for production	Inadequate agricultural practices and technologies
• Frostbites and tissue necroses, crop freezing • Chlorosis • Low fertilization • Poor nutrient uptake • Reduced growth • Degradation of qualities • Lodging • Reduced period of grain filling • Empty grains • Sprouting on spike/cob • Reduced grain and fruit quality • Reduced yield	• Surface waters ponding • Reduced soil quality (fertility) • Reduced arable areas • Increased soil moisture • Shorter or longer growing cycle • More intense outbreaks of existing diseases and pests and emergence of new invasive organisms • Greater weed growth • Deteriorated quality of water used for irrigation • Dry furrows • Cracked soil	• Delayed sowing • Resowing and replanting • Damages to equipment and technology (greenhouses) • Difficulties in the use of machinery • Difficulties in transporting agricultural products • More frequent and complex crop protection • Postponed harvest • Longer seed drying • More complicated processing, with more losses

Natural disasters in **fruit production** also lead to reduced fruit yield and quality in the year of the disaster or the following year. In addition, some disasters, such as extremely low temperatures during dormancy, large quantities of precipitation leading to soil puddling, high winds, extreme hailstorms and similar may permanently destroy orchards (Table 2).

Table 2: Effects of climate related disasters in fruit production

Natural disaster	Effect
Low below-zero temperatures during dormancy	Reduced yield, death of whole plants
High temperatures during dormancy	Reduced yield
Low below-zero temperatures after beginning of vegetation	Reduced yield
Low above-zero temperatures during flowering	Reduced yield, reduced fruit quality
High temperatures during vegetation	Reduced fruit quality, reduced fertility the following year
Heavy rainfalls	Reduced fruit quality, reduced fertility, drying of plants due to root system asphyxiation, breakage of plants under snow
Insufficient amounts of precipitation (drought)	Reduced fruit quality, reduced yield, reduced fertility the following year
Hail	Reduced fruit quality, reduced yield, reduced fertility the following year, permanent destruction of trees
High winds	Reduced fruit quality, reduced yields, permanent destruction of trees, branch breakage

One of the effects of changed climate conditions is the **emergence of new (foreign, incoming from other continents) pests, diseases and weeds**. The types of microorganisms, plants and animals that come to a new area often become invasive, and as such are mostly very harmful. In addition to climate change, this is largely contributed also by globalization, that is, increased transport of persons and goods. Invasive species are often inadvertently introduced into new territories where, if the conditions of the environment are suitable, they develop normally and increase in numbers, and also become more harmful over time. During the past ten or so years many new pests and diseases have been registered in Serbia, and there have been increases in the harmfulness of invasive weeds brought in earlier. As an illustration, during the past 10 years, even 10 new species of aphids (Hemiptera: Aphididae) [P.4, P.5, P.6 P.7] have been introduced.

Potato tuber moth, *Phthorimaea operculella Zeller* (Lepidoptera: Gelechiidae), represents a very dangerous pest of potato in tropical and subtropical areas, and since 2011, it can also be found in Serbia [P.8]. This species thrives on changed climate conditions with long warm and dry periods and reduced quantities of rainfall in summer months. The insect brings harm by damaging tubers in the field or in storage. In recent years, enormous damage has been recorded made by this insect in the territory of West Serbia. The damage is enormous, even up to 100% [P.9]. On many fields, the yield remained on the field, and on some, potatoes were not even taken out. Even more damage was done on stored tubes. From the eggs on the surface of the tube, the caterpillars hatch and drill their way into the tube tissue. Inside the tubes they make corridors, which makes them unusable, and various pathogens develop. This is why the price of potatoes has been very high in Serbia in recent years, despite the imports of mercantile potatoes and considerable funds allocated to this.

Brown marmorated stink bug, *Halyomorpha halys* (Pentatomidae, Hemiptera) is an invasive species, native to Asia, with extremely high potentials to become an economically significant pest for a large number of cultivated plants. Brown marmorated stink bug was registered for the first time in October 2015 near Vršac and Belgrade, and since then it has been spreading and can now be found throughout Vojvodina and in northern parts of Serbia proper [P.10]. It causes severe damage to tomatoes and other vegetable species, but also damages apples and grapes. Damage is also caused by both larvae and adult insects by sucking plant juices out of the above-ground parts of plants.

Image 3: Brown marmorated stink bug larvae and newly hatched insects (Photo: Olivera Petrović Obradović)

Southern green shield bug, *Nezara viridula* (Pentatomidae, Hemiptera) is also an insect species that came to Serbia because of climate change. It is native to Ethiopia, and has been here for the last 10 years, with related damages increasing each year simultaneously with an increase in its distribution. It causes the greatest damage to paprika, tomato, potato, green beans, soy and corn crops, as well as to fruit orchards and vineyards.

The prominent rising trend in air temperature and long-term droughts also have an impact on the number of pests that were there before but in lower numbers. The yellow clover aphid, *Therioaphis trifolii* (Monell) (Hemiptera, Aphididae), existed here twenty years ago, but in small stocks, but the results of the monitoring of the stocks in recent years show that now it is much more numerous. It is an efficient vector of plant viruses, because it produces a large number of flying insects and as such is probably responsible for rapid deterioration and short lifespan of alfalfa in recent years [P.11].

Image 4: **Southern green shield bug larvae on soy and grapefruit leaves (Photo: Olivera Petrović Obradović)**

There is real danger of another Asian aphid coming to Serbia, the so-called blue alfalfa aphid, *Acyrthosiphon kondoi*, which has already been registered in the South of Europe [P.12].

Image 5: **T. trifolii – with wings and without (Photo: Olivera Petrović Obradović)**

Heliothis peltigera (Dennis & Schiffermüller, 1775) is a moth species of the family Noctudiae, order Lepidoptera. Although it has been known in Serbia since the beginning of the last century, increased numbers on cultivated plants were recorded only during 2015 [P.13]. By its size and patterns, the species is similar to the cotton bollworm/corn earworm (*Helicoverpa armigera* Hübner, 1808, also fam. Noctuidae, order Lepidoptera). Both species are native to the Mediterranean, both are migrants and both have become pests only during the last 10 or 15 years, primarily due to changed climate conditions. The caterpillars of these species are extremely polyphagous, which makes them potentially dangerous for many cultivated plants (sunflower, soy, vegetables, flowers, corn, etc.).

In recent years, an increase in the number of the common vole (Microtus arvalis) has been recorded in Serbia [P.14]. It is considered that this was particularly aided by favourable weather conditions during the autumn and winter in 2012 and 2013, without frosts, with long-term drought and increased temperatures. The increased stocks of rodents in some areas were also aided by heavy rainfall in the spring, which caused a rise in ground water levels and massive migrations of rodents to higher areas, as well as the migration of rodents from one type of plants to the next, which also led to a reduction in the yield of wheat and barley of as high as 70%, with findings of high abundance of the common vole (over 50,000 holes/ha). The high abundance of the common vole was also recorded in oats crops, where economic losses amounted to 80%. Damage was made to the crops of sugar beet, corn and new orchards [P.14].

Pathogens leading to the occurrence of plant diseases are highly dependent on the conditions in the environment. In higher temperatures, they develop more quickly and massively, which leads to a decrease in the quality and quantity of yield, appearance of mycotoxins (aflatoxin, fumonisin) in food and animal feed, and even leads to allergies in humans.

The emergence of corn ear rots in 2012, and later also the emergence of mycotoxins in milk, were in direct connection with the impact of climate-related factors. It is considered that the emergence of fungus of the *Aspergillus* genus, producing mycotoxins, was aided by high temperatures, long-term drought between flowering and dough stage of corn maturity and early high incidence of the European corn worm, drilling corridors in corn ears, which created favourable conditions for the development of parasitic fungus. A detailed analysis of corn in Serbia found for the first time the fungus *Aspergillus parasiticus*, in addition to two other known species (*Aspergillus flavu*s and *A. nige*r) [P.15].

Spotted wing drosophila, *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae), causes damage to the production of berries. This invasive harmful species, native to South-East Asia, was registered for the first time in Serbia in 2014 [P.16]. The female spotted wing drosophila lays eggs in healthy fruits, after which white worm-like larvae, up-to 4mm long, hatch, feeding on the meat of the fruit, and attacked fruits deteriorate completely, which leads to significant economic damage. The spectrum of host plants is very broad, including cultivated crops, as well as wild fruit species. Here in Serbia, damage has already been recorded on raspberries, blackberries, strawberries, plums, sweet cherries, peaches, apples, pears, cherry plums, vines, figs and elderberries. The species has been found in all parts of the country, both in lower areas and on mountain tops.

In 2009, it was the first time that an aphid, *Aphis spiraecola* (Image 6), native to Asia, was found in Serbia, which had long been a problem in the Mediterranean on citrus trees, and in the last decades started spreading to Northern parts of Europe. The importance of this species is reflected in the fact that, despite its name, it is very polyphagous, it is the vector of numerous plant viruses and it is resistant to many insecticides, making it very difficult to control.

Image 6: *Aphis spiraecola* on an apple (Photo: Olivera Petrović Obradović)

Mediterranean flat-headed root-borer, (*Capnodis tenebrionis* L, Buprestidae) is a pest that has in the past years led to drying and destruction of sour cherry trees in southern parts of Serbia (around Niš and Leskovac) (Image 7). This year, however, drying of cherry trees was recorded in the vicinity of Grocka, too. The damage is huge and very difficult to control and mostly unsuccessful. The flat-headed root-borer is a Mediterranean species spreading its distribution to the north, most commonly attacking sour cherry trees, but also other similar plants.

Image 7: Dry sour cherry tree due to the feeding of Mediterranean flat-headed root-borer larvae (Photo: Slaven Prodanović) and Mediterranean flat-headed root-borer larvae that caused the drying (Photo: Olivera Petrović-Obradović)

Aceria kuko *(Kishida) (Acari: Eriophyoidea)* is an eriophyoid mite registered in Serbia in 2015, imported on its host – goji seedlings, grown here since recently. Even though goji is cultivated on small areas, this mite is potentially dangerous because it can also develop on paprika and other similar plants [P.17].

A serious threat to fruit production is posed by the **phytopathogenic bacterium** *Xylella fastidiosa*, which for now has not been found in our country, but the effects on agriculture would be immeasurable if it were to arrive. It is a pathogen attacking a large number of perennials. It is transmitted by infected plant material and insects – small cicadas of the families Cercopidae and Cicadellidae (Hemiptera). It was registered in Europe for the first time in 2013, and since then millions of olive trees have been destroyed in Italy because of the infection with this bacterium. There are no olives in Serbia, but they pose potential threat to vine, stone fruits, some decorative plants and spontaneous flora [P.18].

It is well-known that **weeds**, much more easily than cultivated plants, adapt to changes in the environment and more readily endure adverse climate change. This phenomenon specifically relates to invasive weeds, 19 of which are the most important ones in Serbia, according to Vrbničanin et al. [P.19]. The common ragweed (*Ambrosia artemisifolia* L.) must be mentioned here, which is primarily known for its abundant production of pollen which causes allergies in humans. Thirty years ago, it could be found only in Vojvodina, and today it has spread also through the southern parts of Serbia, found at even 1,000 m above-sea level. Japanese knotweed (*Falliopa japonic*a (Houtt.) Ronse Decraene), a shrub, is in great expansion here, and was not to be found only a few decades ago. It is very aggressive and invasive, forms dense clusters and quickly starts behaving as a monoculture. Jerusalem artichoke, gaint marshelder, sunflower broomrape, broad cocklebur and spiny cocklebur are also very aggressive weeds, the distribution of which in Serbia is continuously growing, and they mostly spread from the north towards the south of the country. Weeds lead to changes in vegetation, changes in seed reserves in the soil and changes in microflora. Also, weeds often develop resistance to herbicides which makes it more difficult to control them, reduce yield, but also lead to pollution of the environment.

It is difficult to determine direct effects of climate change to **livestock production**, as well as to humans. Malnutrition, slower growth or mortality can be caused by a number of factors, starting with high temperatures, poor quality and/or inadequate nutrition that can lead to disruptions to the digestive tract, deterioration of breeding conditions, pollution of drinking water, diseases or pests. If nearly all of the above-mentioned conditions are met in animal breeding, the impact of climate change can be detected only, for example, if an extreme event occurs, such as the duration of a heat wave and/or inability to provide adequate conditions for animal breeding, or the outbreak of a disease that has not been detected prior to that.

Sustainable agricultural production, such as organic plant or livestock production or integral production, is more exposed to the effects of climate change than conventional agricultural production, because of the complexities of various biological, physical, agro-technical measures it is based on. This complexity is also reflected in the UNCED (UN Conference on Environment and Development) Agenda 21 Action Plan, which states that "major adjustments are needed in agricultural, environmental and macroeconomic policy, at both national and international levels, in developed as well as developing countries, to create the conditions for sustainable agriculture and rural development". Climate change hinders diversification and numerous activities in integrated agricultural systems and also contributes to the disappearance of certain species, genes and ecosystems, which is why it presents an obstacle to the implementation of various measures for sustainable agricultural production.

Climate change can have damaging effects in terms of reduction or loss of agrobiodiversity, which is the diversity of genetic resources of cultivated plants, animals and microorganisms used in agriculture. Agricultural diversity is the result of interactions among 1) genetic resources, 2) the environment and 3) management systems and practices used for land and water resources by culturally diverse peoples.

In Serbia, numerous indigenous populations and old varieties and breeds, which were environmentally adapted to certain areas, are endangered because of climate change [P.20]. Examples of such local varieties are the cabbage from Futog, the Somborka pepper, and the Gradištanac beans. In animal breeding, examples of indigenous breeds are the domestic mountain horse, Buša cattle, Mangulica, Moravka and Resavka pigs, sheep breeds including Čokanska cigaja and Pramenka with Krivovirski, Pirotski, Lipski, Karakačanski and Vlaško vitorogi strains, poultry breeds Svrljiška kokoš, Somborska kaporka, Banatski golišijan and others. The loss of biodiversity of the flora and fauna due to climate change may lead to changes in the composition and productive capacities of permanent natural or semi-natural grasslands, especially in South-East regions of Serbia, where a decrease in rainfall is expected, which will result in reduced animal productivity in extensive livestock production, as well as have negative impacts on their health, resistance to disease, etc. Also, in fruit production, significant changes have occurred to the assortment. Some old indigenous fruit varieties, such as apples Budimka, Kolačara, Krstovača and Petrovača; pears Lubeničarka, Karamanka, Jerebija or plums Požegača and Crvena Ranka are nearly completely lost. There are several reasons for this, but some of the most important ones include the change of the climate to which these varieties were adapted, smaller rural population, introduction of new technologies to which these variates are not adapted, emergence of new diseases and new pests, such as the fire blight of apple, plum pox virus, pear psylla, etc. The task of all fruit growers is to attempt to preserve these varieties, both in the production and in collections, i.e. gene banks.

Climate change erodes agroecosystems. Agricultural areas of high natural value in terms of multifunctional agriculture are directly threatened, because it is the role of agroecosystems to provide a series of ecosystem services that can be measured materially (for example, loss in yield or production potential of domestic animals) or immaterially in rural areas and the entire rural population and society (loss of habitat of plant species, butterflies, birds; loss of traditional cultural landscapes, loss of compensatory capacities of agroecosystems for the circulation of nutrients in the soil, water and air purification, etc.).

Erosion related damages to agrobiodiversity cannot be restored; once lost natural resource cannot be created again using technology. In this sense, it is important to develop National Gene Banks to preserve agro-biodiversity, and to sustainably manage agro-ecosystems, that is, land and water resources. The promotion of organic agricultural production or integral production can particularly help preserve agrobiodiversity, because it is based on use of different agricultural species and populations in smaller areas, sustainable use of land and water, as well as extremely diverse agricultural activities.

Risks and effects

The position of agricultural land in terms of topography and climate characteristics in Serbia has historically created issues related to water excess rather than droughts, wherefore construction of drainage systems has been given priority over irrigation. However, in recent years, **severe and extreme droughts followed by high temperatures** have been recorded on the territory of Serbia [P.21, P.22, P.23].

Studies have shown [P.24] that during the past 12 years, there were 4 autumn droughts, which is not suitable for winter crops and grasslands (meadows, pastures), while there were 8 summer droughts, which is harmful to the entire plant production. Therefore, we are talking about regular droughts, almost every year or once in two years. The intensity of droughts varies from catastrophic (2012, 2000), to moderate and mild droughts. Looking at perennials, which are grown on more shallow soils and grasslands, the most intense negative impact is sustained when there are consecutive both autumn-spring and summer droughts, such as the ones in 2006/2007 and 2007, particularly in East Serbia, then 2011/2012 and summer 2012 throughout the country. Therefore, the observed data unambiguously show regular occurrence of droughts, in terms of both time and space, in all parts of the country, even in Pešter, where it threatens the grazing of livestock. If we look at the past several decades [P.21, P.24, P.25], severe and catastrophic droughts occurred throughout the country, such as the ones in the years 2000, 1995, 1993, etc.

Dry areas, with precipitation under 600mm, are particularly vulnerable, which can be found in the North East of the country in Vojvodina, valley of the lower course of Velika Morava, valley of South Morava, flatlands of Negotin and parts of Kosovo and Metohija.

For the purposes of assessing future drought-related risks, an analysis of water deficits for corn, wheat, fodder plants (clover, grass mixes, pastures), paprika, apples, pears, sour and sweet cherries, plums, apricots and peaches was conducted. The deficits for corn and wheat were determined using the AquaCrop model [P.26], while the water balance method was used for other cultures. Five localities were chosen (Rimski Šančevi, Valjevo, Kragujevac, Negotin and Leskovac), in order to represent risks of drought in the entire country. Input data on climate used were the results of an ensemble of nine EURO-CORDEX regional climate models. The median of the results received for each member of the ensemble was taken as the most likely value. The reference (baseline) period was 1986-2005, future periods: 2016-2035 (near future), 2046-2065 (mid-century) and 2080-2099 (end of the century). The analyses were done using the RCP8.5 scenario (scenario of constant CO2 increase), which should encompass the most probable range of possible future outcomes.

Table 3: Wheat yields (t/ha) calculated using AquaCrop model, for 9 climate models and RCP8.5 scenario

Location		Rimski Šančevi				Valjevo				Kragujevac				Negotin				Leskovac			
Period		Min.	Max.	Med.	Change	Min.	Max.	Med.	Change	Min.	Max.	Med.	Change	Min.	Max.	Med.	Change	Min.	Max.	Med.	Change
1986-2005	average	5.5	6.2	5.7		5.2	5.9	5.5		4.9	6.4	5.4		4.7	5.8	5.3		4.8	6.1	5.3	
2016-2035	average	4.7	6.7	5.8	2.9	4.6	6.8	5.5	**-1.3**	4.7	6.5	5.8	**6.8**	5.1	6.2	5.7	**8.3**	5.0	6.1	5.4	**3.0**
2046-2065	average	4.3	6.0	5.6	-1.8	4.5	6.4	5.0	**-9.3**	4.8	7.0	5.0	**-7.3**	5.1	6.7	5.6	**7.1**	3.4	6.2	5.1	**-3.0**
2080-2099	average	3.5	6.1	5.5	-3.8	3	5.2	4.6	**-17.2**	2.9	7.3	5.4	**0.1**	3.8	6.5	5.4	**1.9**	4.5	6.1	5.4	**1.9**

Water deficits for wheat will remain within the range of current values, because the total precipitation by the end of century of over 400mm (Table 3) on all observed areas shows that there will be enough water to generate high yield. However, there will be great variations in yields from one year to the next, due to autumn droughts, which will delay the sprouting of crops. Even though autumn rainfall will ensure sowing and sprouting within optimum time for sowing, the issues of autumn drought will frequently occur. In addition to drought, increased soil moisture during vegetation will be an issue for the growth of crops, so in the future, drainage measures will also need attention. Higher deficits will be avoided due to milder winters, shorter dormancy periods, flowering in times of more favourable temperatures and faster ripening of wheat.

Irrigation norms for achieving high and stable **yield of maize** will not change significantly, neither in the North nor in the South of the country, but only if the sowing is done within optimum timeframes (Table 4). Any delays would pose the risk of corn entering into the stage of silking, pollination and formation of kernels – in the period of drought and high temperatures, i.e. when it is the most sensitive to water shortage and temperature stress and in this way may reduce its yield. Namely, such result is not an effect of large amounts of precipitation, but rather an increase in air temperature in spring, which will enable earlier sowing by about 5 days (in Leskovac even up to 10 days), by 10 days at mid-century and by even 20 days at the end of the century in all areas. Warmer climate will also reduce the duration of all phenophases, which will ultimately result in shorter growing cycles. Favourable temperatures, together with precipitation, will lead to high yields (Table 5) on deep and fertile fields, which were also used for yield simulation.

Therefore, there will be risks of drought on shallow and sandy terrains, especially those soils that will not allow for soil preparation and sowing within optimum timeframes. These are mainly flatland hydromorphic soils in river valleys and basins that are often too moist, and there are 50% such soils.

In our climate conditions, paprika cannot be grown without irrigation. Average water deficits under present conditions have been calculated based on data provided by the model (around 450 mm ±215) and coincide with the observed 485–630 mm [P.27, P.28]., Increased impacts of drought can be expected in the near future and at mid-century, because an expected increase in the needs for irrigation of 0.7-11.6%. However, at the end of the century, water deficits may be as high as 27-35.6% (Table 6).

Table 4: Water deficits (irrigation norms) for corn in present and future climate conditions in the areas of Rimski Šančevi and Leskovac

Location		Rimski Šančevi				Leskovac			
Period/deficit		Min	Max	Median	**Change (%)**	Min	Max	Median	**Change (%)**
1986-2005	average	187	269	212		214	333	272	
2016-2035	average	204	267	240	**13.0**	220	334	302	**11.2**
2046-2065	average	180	266	201	**-5.2**	244	335	284	**4.5**
2081-2100	average	175	256	204	**-4.0**	246	335	276	**1.7**

Meadows and pastures, even though they are not as sensitive to the lack of water as paprika, will also be exposed to increased risk of droughts. Lack of water already comes about at the end of May, when water stored in the soil has been exhausted, and will last until the first heavier rains in September. Even though grass has a mechanism to survive periods of drought, if it is severe, it may bring about complete drying out of certain types of grasses. In the future more severe droughts may be expected, i.e. a 7% increase in water deficit at the beginning of the century, to 41.9% at the end of the century (Table 7).

The technology of growing new apple and pear varieties includes, among other things, maintaining the root system at a depth of 0.3-0.5 m. This achieves efficient water and nutrient absorption from the most fertile part of the soil. Such technology requires the application of irrigation and fertigation, even in those areas where, traditionally, apples were produced in natural water supply conditions. Growing apples and pears in this way requires more water than traditionally, when deep root system was used by the fruit to draw winter accumulations of water from deeper layers of the soil. Recent studies have shown that a modern apple orchard needs between 265 and 460 mm of water [P. 29], and this is under conditions of reduced consumption, when apples are protected using hail nets, which coincides with the results of these studies. In future climate conditions, not only apples, but pears, sour and sweet cherries, both those grown traditionally and those in conventional production, will need more water, 8% at the beginning of the century and 26% by the end of the century, because of more severe droughts (Table 8). This level of drought will undoubtedly affect fruit yield and quality. Periods of drought will begin as early as mid-May on more shallow soils and early in June on deeper and more fertile ones, when water stored within the soil have been depleted. Increased impacts of drought will also impact reduced air humidity, which is highly undesirable in the period of flowering and pollination.

Somewhat lower water deficit levels will also apply to plums, apricots and peaches, but with the same trends as described for above-mentioned fruits.

Water deficits in orchards can be reduced if they are grown without grassland in between rows. However, because of the preservation of soil from erosion, this practice is not recommended.

Future projections for climate parameters indicate that droughts will occur with the same or increased intensity, which should be a red flag for decision-makers to strategically plan the development of irrigation, not only at the local but also at the regional level. Droughts will pose the highest threats to all summer crops on shallow soils, followed by pastures and orchards, followed by summer cultivars on deeper soils, where winter moisture reserves facilitate survival during droughts. Needs for water will increase between 1 and 8% in the near future, 3.7-13.9% mid-century and 22.4-41.9% by the end of the century. Increased use of water resources for irrigation may have a negative impact on aquatic ecosystems.

Serbia is located in a specific area, where droughts and excess water appear periodically. There is a pronounced disbalance of precipitation, that is excess water in winter-spring periods and droughts in autumn and summer period, which calls for the need to achieve a balance in the water-air regime and provide conditions for stable agricultural production.

Excess waters pose continuous or occasional threats to 2.6 million ha of agricultural land, while 955,000 ha cannot be used without applying drainage systems. According to the planning documents [P.35], in the development period by 2034, drainage should cover around 1,127,000 ha of soil. There are three operational objectives in the projection of agricultural land drainage,: Upgrading drainage system to prevent water logging; Efficient and coordinated operational defence from internal waters; and Regular maintenance and status checks of water structures.

This paper shows the analysis of climate change in several weather stations in Serbia, which were chosen as representative ones for the areas with significant drainage systems (in the valleys of Sava, Danube, Great and West Morava rivers). The following stations were selected: Sremska Mitrovica, Novi Sad, Negotin, Niš and Čačak, and as baseline for analysis, data on maximum daily precipitation were used (over the period of one, two, three and five days). These data also serve to calculate drainage hydromodules as some of the most important design criteria, and so the expected changes in the values of maximum daily precipitation imply changes in the management of drainage systems, that is to review changed needs for drainage. Five periods were selected (1950-1980, 1980-2010, 2010-2040, 2040-2070. and 2070-2100) and calculated amounts of precipitation of probability 10 and 20%, that is the reoccurrence period once in 10 and 5 years. Presented values show medians for 9 models of the RCP8.5 scenario. On the Čačak station (Chart 1), we can see that for one-day precipitation, an increase of 4.5% is expected relative to the 1950-1980 period and for two-day precipitation – 6.6% as late as in the 2070-2100 period, while the increase of three-day and five-day precipitation in this period is lower (4.6% and 3.5% respectively). In the period 2040-2070, an increase is expected only for two-day precipitation (5.1%). Similar trends can also be seen for precipitation with probability of 10%.

Table 5: Corn yields (t/ha) calculated using AquaCrop model, for 9 climate models and RCP8.5 scenario

Location		Rimski Šančevi				Valjevo				Kragujevac				Negotin				Leskovac			
Period		Min.	Max.	Med.	Change	Min.	Max.	Med.	Change	Min.	Max.	Med.	Change	Min.	Max.	Med.	Change	Min.	Max.	Med.	Change
1986-2005	average	11.2	11.7	11.5		11.7	12.1	11.9		11.6	12.1	11.8		9.9	10.7	10.6		11.4	12.2	11.7	
2016-2035	average	11	11.8	11.5	**-0.3**	11.4	12.3	11.9	**0.1**	11.5	12.3	11.8	**-0.3**	10.1	10.9	10.6	**-0.1**	11.4	12.4	11.7	**-0.3**
2046-2065	average	10.7	11.8	11.6	**-3.9**	11.6	12	11.8	**-0.6**	11.1	12	11.7	**-1.0**	10	10.9	10.7	**1.6**	11	11.9	11.7	**-0.7**
2080-2099	average	10.2	11.6	11.1	**-.3.5**	10.5	11.6	11.2	**-5.7**	10.6	11.6	11.2	**-5.5**	9.7	11	10.3	**-2.3**	10.6	11.3	11.1	**-5.6**

Table 6: Water deficit (mm) for paprika, under present and future climate conditions for the RCP8.5 scenario

Location		Novi Sad				Valjevo				Kragujevac				Negotin				Leskovac			
Period/deficit		Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)
1986-2005	average	-303	-380	-341		-152	-290	-252		-301	-4019	-365		-429	-484	-444		-353	-482	-451	
2016-2035	average	-302	-432	-350	**2.60**	-185	-378	-265	**5.5**	-331	-459	-363	**0.7**	-421	-535	-472	**6.25**	-402	-546	-481	**7**
2046-2065	average	-315	-510	-365	**6.9**	-440	-251	-280	**10.1**	-369	-538	-406	**11.2**	-454	-588	-479	**7.3**	-451	-592	-503	**11.6**
2081-2100	average	-409	-602	-442	**29.4**	-331	-527	-391	**35.6**	-444	-624	-492	**34.6**	-532	-677	-572	**22.4**	-520	-669	-575	**27.6**

Table 7: Water deficit (mm) for meadows and pastures, under present and future climate conditions for the RCP8.5 scenario

Location		Novi Sad				Valjevo				Kragujevac				Negotin				Leskovac			
Period/deficit		Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)
1986-2005	average	-254	-345	-302		-238	-361	-313		-66	-223	-168		-385	-447	-410		-286	-428	-390	
2016-2035	average	-262	-393	-320	**6.0**	-289	-410	-309	**1.20**	-130	-312	-182	**7.9**	-372	-479	-438	**6.8**	-305	-479	-415	**7**
2046-2065	average	-262	-470	-313	**3.7**	-314	-516	-356	**13.9**	-179	-389	-190	**11.4**	-412	-495	-443	**7.3**	-349	-494	-415	**6.4**
2081-2100	average	-345	-530	-388	**28.4**	-356	-559	-433	**38.6**	-196	-422	-290	**41.9**	-476	-659	-535	**23.3**	-384	-622	-508	**30.5**

Table 8: Water deficit (mm) for apples, pears, sour cherries under present and future climate conditions for the RCP8.5 scenario

Location		Novi Sad				Valjevo				Kragujevac				Negotin				Leskovac			
Period/deficit		Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)	Min.	Max.	Med.	Change (%)
1986-2005	average	-374	-469	-426		-361	-490	-440		-181	-343	-289		-518	-580	-540		-415	567	-529	
2016-2035	average	-384	-524	-447	**4,9**	-418	-542	-439	**0,30**	-247	-400	-304	**5,5**	-505	-617	-571	**5,8**	-437	624	-572	**8**
2046-2065	average	-388	-606	-443	**4,0**	-445	-658	-489	**11,1**	-302	-523	-317	**8,8**	-547	-715	-578	**6,6**	-514	-696	-576	**9**
2081-2100	average	-489	-677	-523	**22,9**	-539	-714	-577	**31,2**	-325	-567	-428	**32,5**	-619	-799	-683	**20,9**	625	-777	-666	**26,0**

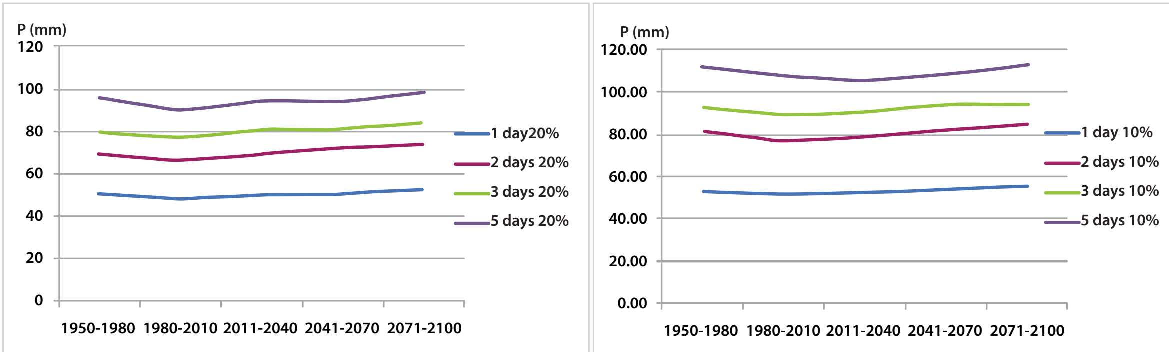


Chart 1: Probabilities of maximum 1-, 2-, 3- and 5-day precipitation with probability of 10% (a) and 20% (b) in Čačak

When it comes to Negotin (Chart 2), data show that the increase for one-day precipitation is the highest in the period 2010-2040, while by the end of the century the expected increase is up to 3.9%. However, when it comes to two-day, three-day and five-day precipitation, the increase is somewhat higher (1.8-4.1% in the period 2040-2070, but also 7.3-12.7% relative to the initial period of the last three decades of the 21st century).

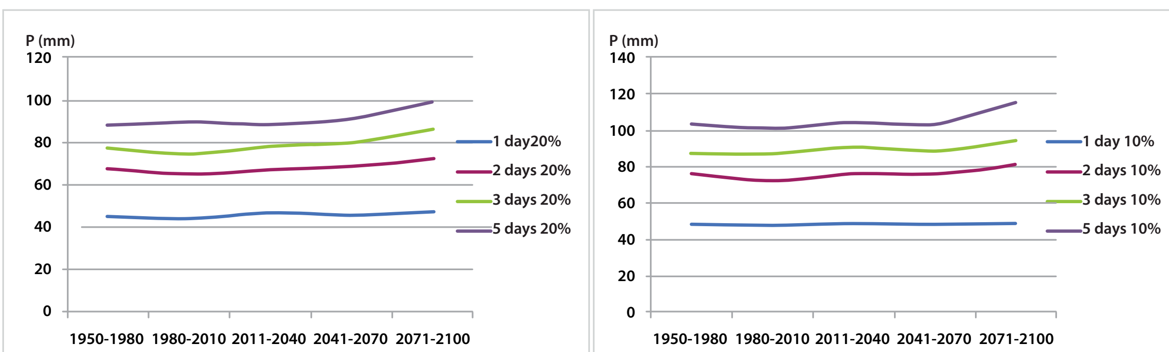


Chart 2: Probability of maximum 1-, 2-, 3- and 5-day precipitation with probability of 10% (a) and 20% (b) in Negotin

Similar trends can also be seen in Sremska Mitrovica (Chart 3): increase of total precipitation by 8.5-11.7% in the last decades of the 21st century. In Sremska Mitrovica, however, there is also an identified increase of 4.8%-6.9% already in the period 2040-2070.

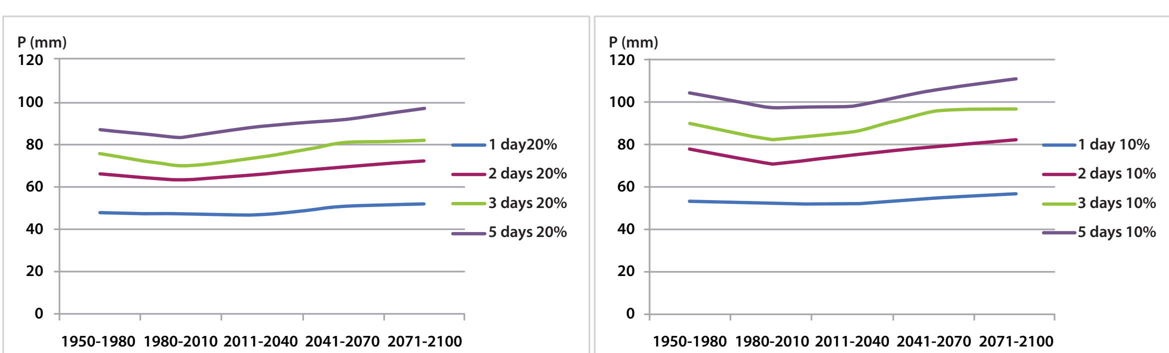
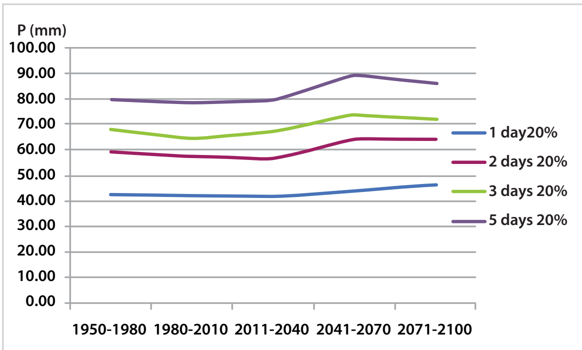


Chart 3: Probability of maximum 1-, 2-, 3- and 5-day precipitation with probability of 10% (a) and 20% (b) in Sremska Mitrovica

Data for Niš show that significant changes of maximum one-day precipitation are not expected, but that the increase of maximum two-day, three-day and five-day precipitation is the highest in the period 2040-2070 (12.1-17.5%), while in the period 2070-2100, the increase is much lower (2.7-7.1%). Similar as for the above-mentioned stations, values for the Novi Sad station show an increase in the second half of the 21st century, by 6.4-12.4% (Chart 4).



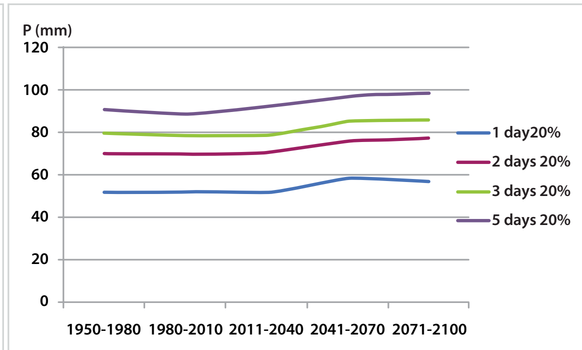


Chart 4: Probability for maximum 1-, 2-, 3- and 5-day precipitation with probability of 10% for Niš (a) and Novi Sad (b)

2.3 Analysis of the importance of climate change risks and effects

Based on the presented climate projections by the end of the century (Table 1), the expert team has assessed the importance of risks of climate change impacts on agriculture, including the assessment of urgency to adopt the decision on initiating adaptation measures. An online survey (https://goo.gl/forms/VfM5F-Mt1ENojWOB73) [P.30] was conducted to assess the degree of concurrence between the expert team and agricultural producers on climate risks.

The survey was conducted among agricultural producers with the participation of the public. The aim of the survey was to get an answer to the following question, among others: "What are the most important changes to the climate that you have noticed and how have they manifested?" Survey participants included agricultural producers from all areas of agriculture. Crombach's α coefficient was used to test the reliability of the survey. This coefficient indicated a satisfactory reliability of all survey factors.

Received results have shown realistic vulnerabilities of Serbian agriculture, the importance of climate change impacts on agriculture, highlighted risks and contributed to defining adaptation measures.

The list of vulnerabilities of agriculture to climate risks is based on observed events, scientific research, modelling and effects of climate change on yield. The criteria established in the IPCC Fifth Assessment Report were used to identify key risks [P.31].

The list of vulnerabilities of agriculture (Table 9) to climate change impacts includes 9 most important risks. The experts have determined, based on available data, research results and experience, that droughts, high temperatures and hail are of the greatest importance and urgency for Serbian agriculture.

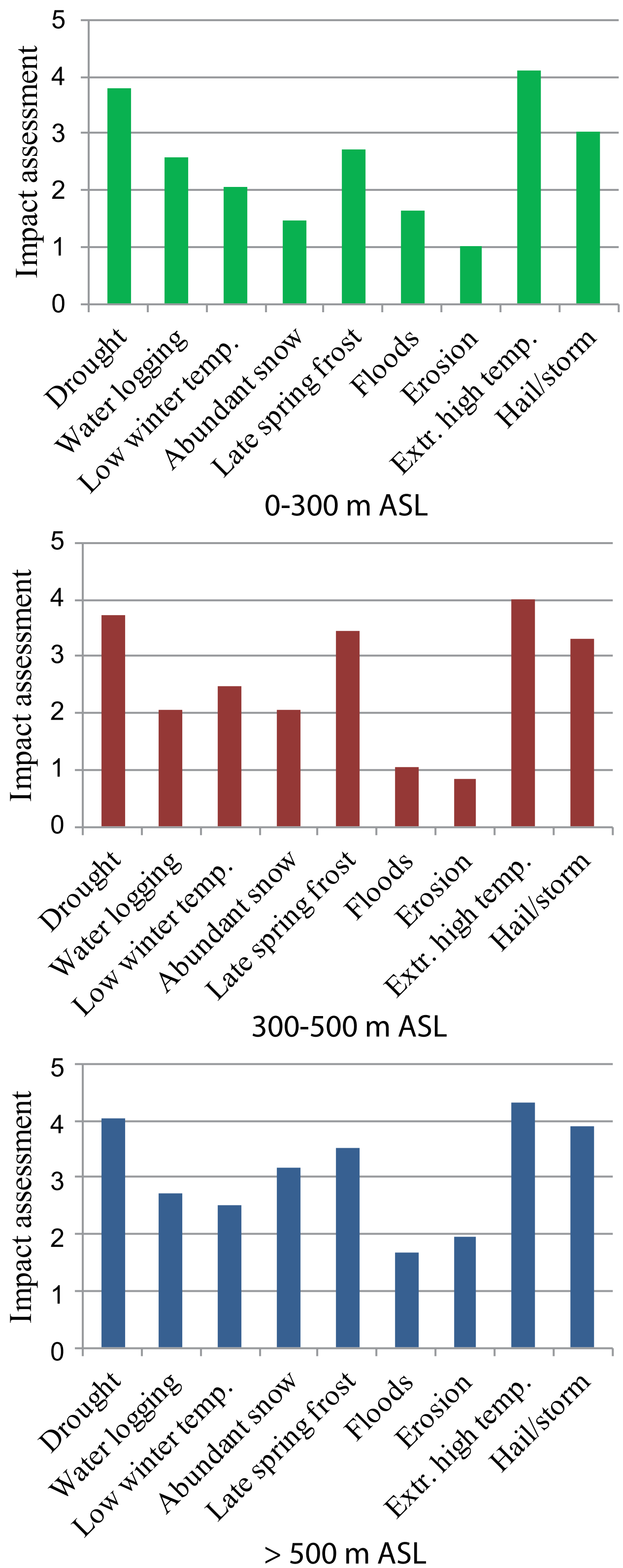
Table 9: List of vulnerabilities of agriculture to climate change impacts and effects on plant production

Impacts	Importance	Urgency	Degree of compliance
Drought	●	▲	+
Water logging (water excess)	○	△	+
Low temperatures in winter	○	△	+
Abundant snow	○	△	+
Late spring frost	○	▲	+
Floods	○	△	±
Erosion	○	△	±
High temperatures	●	▲	+
High winds and hailstorms	●	▲	+
Effects on plant production			
Shorter growing cycles	○	△	±
Postponed harvest and rotting because of rain	○	△	±
Reduced yields	●	▲	+
Emergence of new invasive diseases	●	▲	+
Increased sensitivity to pests	○	△	+
Other impacts	N/A	N/A	N/A

Importance symbols: ● high importance ○ moderate importance N/A – cannot be assessed

Urgency symbols: ▲ urgent △ moderately urgent N/A – not urgent

Degree of trust symbols: + very high ± medium N/A



This evaluation of importance and urgency has been compared with survey results. It has been determined that the risks outlined in the list of vulnerabilities significantly match the personal experiences of 141 agricultural producers from all parts of Serbia, who participated in the survey. They highlight that the most important climate change impacts are in relation to extremely high temperatures, droughts, hailstorms and late spring frosts. Other things, such as waterlogging, abundant snow on greenhouses/tree branches, floods and erosions were also identified, but to a lesser degree, and particularly on higher altitudes (Chart 5).

It should be underlined that there are specificities in the evaluation of importance of climate change impacts among agricultural producers, depending on the position of their property, which is particularly related to altitude. In the opinion of agricultural producers, the highest impact of climate change on agriculture is reflected on crop yields, with higher impacts in the areas on an altitude of 300-500 m. On the territory of the entire country, moderate shortening of vegetative phases of crops has been noticed, which is somewhat more pronounced on higher altitudes (over 500 m ASL). Also, a moderate effect of postponed harvest of fruits and/or crops due to rainfall, which is more pronounced in areas on altitudes of 300-500 m. It is interesting to note that agricultural producers have seen far fewer new invasive species and also, weaker impact on the resistance of existing invasive species (Chart 6).

Chart 5: Assessment rate of climate change impacts by agricultural producers and Agronomist

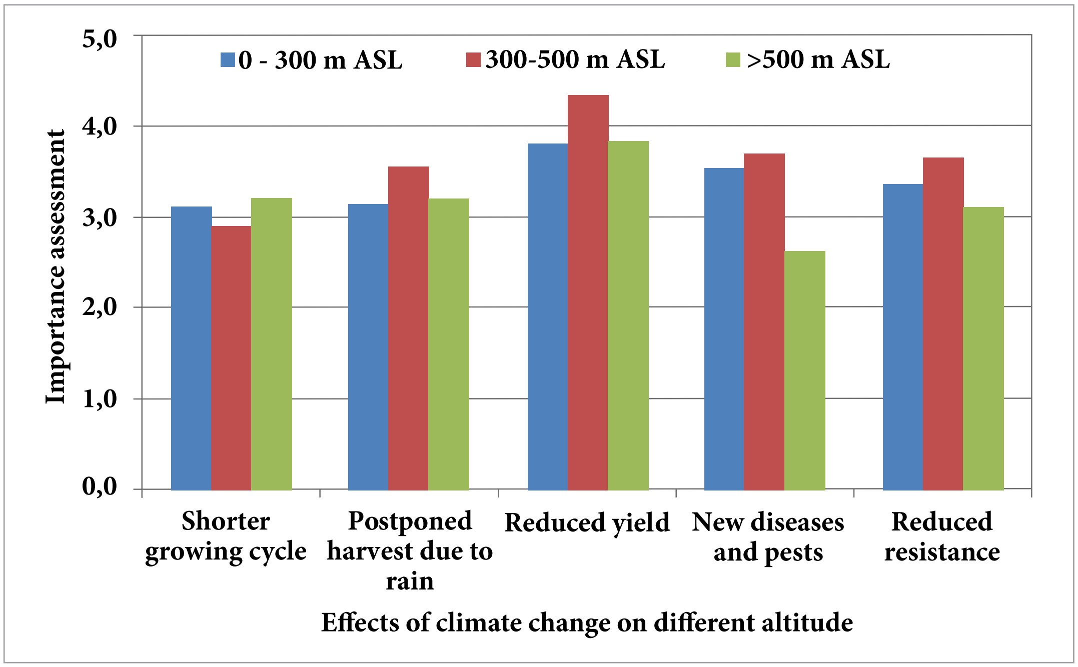


Chart 6: **Effects of climate change according to the opinions of farmers**

Agricultural producers provided qualitative answers to the following question: "Have you identified any positive effects of climate change?". Some of them include: earlier ripening, which can have positive effects on income, because they reach the market sooner; good quality of grapes; drier corn kernels and wheat grains, less energy and time needed for drying; sometimes fewer pests; higher content of sugar in fruit; milder winters on Pešter; changed sowing dates in spring; and similar.

3.
ASSESSMENT OF DAMAGES CAUSED BY CLIMATE CHANGE

The National Adaptation Plan [P.32] presents methodology for **the assessment of damage caused by droughts** for the most important field crops. It was calculated that in the period 1994-2014 direct damages, caused by low yields due to droughts amounted to 4.6 billion USD, which can be taken as a lower estimate, because analysed cultivars are grown only on 43% of total agricultural land. Certainly, the most affected cultivar is maize, with direct loss assessments at 2.2 billion USD. If we add to this the fact that data for clover, alfalfa, melons and pulses were not analysed, and they are also very sensitive to droughts, or the fact that, because of the lack of data damages on fruits were excluded, it is clear that direct damages are much higher than the above.

Damage from water logging are hard to determine, because they do not affect yield as unambiguously as drought does. They are more often reflected indirectly: when moisture is increased for a longer period of time (spring), agricultural production is impeded; sowing is delayed, and thus the plant can enter its sensitive phenophase in the least favourable time (flowering and forming fuits), which has negative effects on yields; the threat to the lowest parts of the field (depressions), which hold water occasionally for longer or shorter periods of time (i.e. ponding water); due to a lack of air, plants suffocate and yield is reduced only on these parts; partially or completely impeded movement of agricultural machinery and application of agro-technical measures; impeded irrigation, and therefore also two sowings annually; impeded sowing of perennial grasses sensitive to water logging (alfalfa) and winter crops, with the prevailing use of summer crops, which is unfavourable from the environmental perspective, and the fact remains that they would be particularly vulnerable in future climate conditions due to further increase in temperatures and intensified droughts during the summer; impeded planting of multi-annual plants; increased moisture in the vicinity of brackish ponds creating additional adverse effects on yield.

Damage to yield/income have always been relative to the "good years", that is, the years of good or at least usual (average) yields. Risks for the production of the most important **field crops** (wheat, corn, sunflower and soy) and vegetables (potato, paprika, tomato, beans and cabbage) should be emphasized, which can lead to an imbalanced diet for the population and threaten Serbian economy. A rising trend of "bad years" has been noticed, with considerable reductions in average yield, for all field crops and vegetables (Table 10).

Table 10: Damage caused by adverse climate impacts on field crop and vegetable yields, losses at Republic of Serbia (RS) level

Year	Plant species (cultivar)	Reduced yield (t/ha) relative to average*	Sowing area (ha)	Producer price per kg**	Estimated damage (in million RSD) at RS level
2010	Barley	0.6	89,937	16.06	867
2012	Maize	2.2	976,020	16.19	34,764
2012	Sugar beet	11.6	69,069	4.24	3,397
2012	Sunflower	0.4	185,918	33.22	2,470
2012	Potato	2.1	52,035	22.78	2,489
2012	Pepper	1.2	11,906	54.34	776
2012	Soybean	1.0	162,714	45.02	7,325
2014	Potato	2.0	51,987	22.78	2,369
2015	Wheat	1.2	589,922	16.77	11,872
2015	Alfalfa	1.0	109,230	11.51	1,257
2015	Clover	1.2	76,625	11.60	1,067
2017	Wheat	1.1	556,115	16.77	10,259
2017	Maize	2.1	1,002,319	16.19	34,078
2018	Tobacco	0.4	5,762	205.15	473

*Yield deviations in the given year from the regression line of average yields in RS for the period 1947-2018, according to SORS data.

**Producer prices in 2017, according to SORS data.

Damage to fruit production due to climate change induced disasters can be very high. If apricot production in Serbia is around 23,000 t, with an average price of 0.3 EUR, we get to the amount of around 7,000,000 EUR. It is considered that once in three years, and in some regions even more often, apricot yield is lost, due to the effects of late spring frost. This leads to the conclusion that for apricot alone, the issue of late spring frost, brings annual damages in the amount of over 2,000,000 EUR. Because of warmer winters, vegetative movements for other fruits are also starting sooner and sooner, resulting in greater damages caused by late spring frosts to economically significant species, such as plum, peach, apricot and apple. Keserović et al. [P.2] report that fruit production in Serbia constitutes 11% of the total value of agricultural production, which has in recent years been around 500,000,000 USD. Gržetić et al. [P.33] report that average annual economic losses due to bad weather and hailstorms in 2005 were at 86 million EUR. The same authors report that one-fifth of total damage caused by bad weather is due to the effects of hail. This leads to the conclusion that damage caused by hail alone can reduce yield in fruit production and reduce the quality of fruits by around 5%. At annual level, this amounts to 20,000,000 EUR. Some years, damage caused by summer temperatures that cause growth cessation and fruit scorch is as high as over 30%, and also affects the quality. For apple alone, with production value of around 100 million EUR, damage caused by high summer temperatures, can be as high as 30 million EUR.

It is difficult to determine the damages that may occur in **livestock production** due to climate change, unless they are fatal to the animals. However, it has been determined that heat waves with extremely high temperatures in the summer may create conditions which, for example, cannot be endured by poultry, and the most extreme effect is animal death. There have been such examples in Serbia. Most often damages are indirect, and they are reflected in the milk capacities of cows or low weight in animals, poor nutrition, etc.

3.1. Assessment of importance of damage by sectors

Previous reports [P.32], as well as this one, show the assessment of damage on field crops. However, it is much harder to assess damage e.g. in fruit production or livestock production due to climate change. For this reason, we asked the following question: "What is the extent of the damage you have experienced from climate change relative to usual yield/income?" Respondents provided real values that are in agreement with the assessment.

There are differences among respondents related to the assessment of climate change damage, depending on the altitude and region of agricultural production and type of production.

Agricultural producers from mountainous terrains report more damage compared to those from flatlands. Agricultural producers from South and East Serbia report the greatest damage caused by climate change, followed by those from Belgrade and Šumadija and West Serbia regions. The smallest damage is reported by respondents from Vojvodina region.

The perception of damage caused by climate change is statistically significantly different for respondents that produce fruit than those that do not (Chart 7). These results are logical, because extremely high temperatures and droughts as the biggest effects of climate change, which must cause damage to fruit production, which is most often done without the use of irrigation in Serbia. In addition, fruit quality and price are also under the influence of hail, and late spring frosts, which is also a significant impact. Damage in field crop and open-field vegetable production was assessed as significant, but with great variations ranging from moderate to significant, which in the long term, is really changing from one year to the next, since nearly entire field crop production and part of vegetable production (beans, peas, potato, onion, garlic) are done without irrigation. Damage to winegrowing is moderate, between 10 and 30% of the usual profits. The impact of climate change on livestock production is reflected only on the production of fodder, so the results received are also in the range of moderate damage, while the least negative impact of climate change is on greenhouse production, up to 10%.

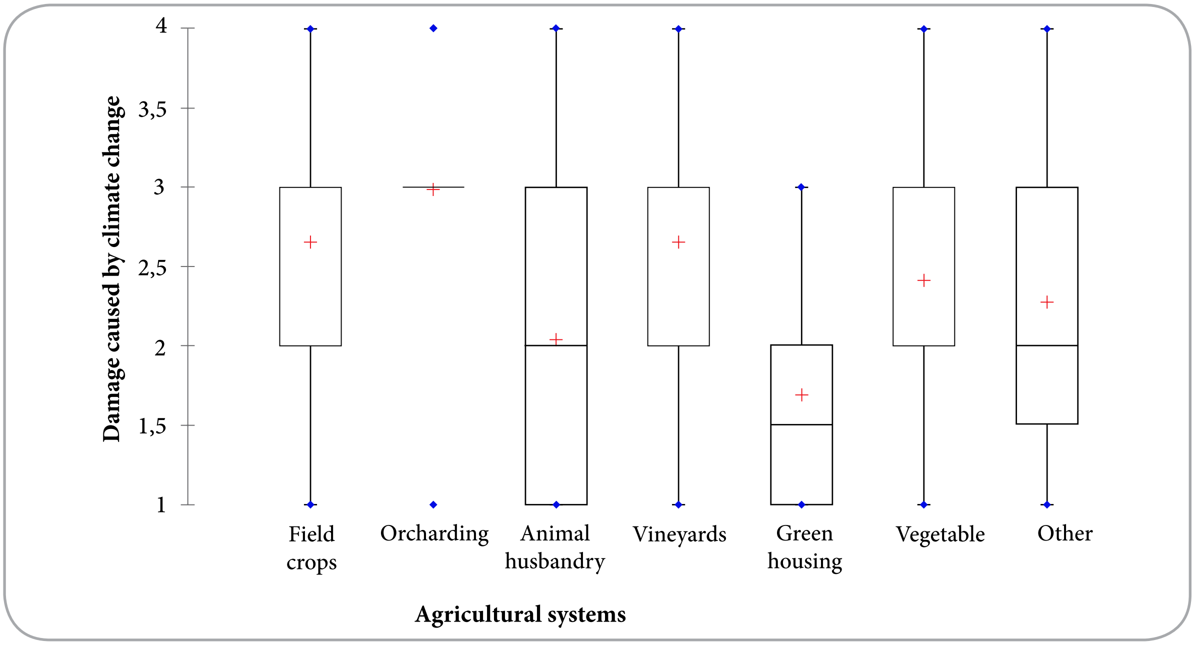


Chart. 7: Damage caused by climate change according to the opinions of agricultural producers / Agronomists

4. ADAPTATION MEASURES

4.1. Adaptation measures at strategic level

For the above-mentioned risks presented in Tables 1 and 2, the expert team concurs with the proposed adaptation measures provided in the Second National Communication [P.34] but has grouped them by method and purpose of implementation (Table 11). The impacts of climate change in agriculture may be individual, synergetic or antagonistic. The effects may appear locally or regionally, with the direction of impact being direct or indirect. Some adaptation measures are multifunctional, such as hail nets, which reduce orchard temperatures, water consumption, thus mitigating drought effects, with efficient water consumption, reducing the risks of fruit scorch, and the impact of hail. In relation to this, the priorities for adaptation measures need to be adopted based on a multi-criteria analysis, more conservatively than the evaluated impacts.

Table 11: Climate change adaptation measures

Adaptation measures to flooding	Construction of drainage systems
	Construction of accumulation lakes or pools
	Erection of embankments
	Restoration of wetlands
	Restoration of vegetation
	Reforestation
	Agricultural insurance against flood damage
Adaptation measures in fruit production and winegrowing	Use of hail nets
	Increased manure and other organic fertilizer input into the soil for fertility and better water retention
	Use of irrigation systems
	Cultivation of spaces in-between rows for reduced water consumption on flat land
	More efficient application of techniques to protect the plants from frost in late spring
	Introduction of alternative, early and table varieties
	Enhanced monitoring for emergence of plant pests and diseases

Adaptation measures to extreme weather conditions	Construction of anti-frost irrigation systems
	Installation of hail nets and/or shade nets to protect the crops from temperatures
	Growing of early-maturing varieties
	Introduction of new cultivars/varieties tolerant to high temperatures
	Introduction of more cultivars in the rotation of crops due to shorter growing cycles
	Use of high-yield varieties and hybrids in settings with applied irrigation (for more efficient water, nutrient and energy use)
	Enlarging areas under winter crops
	Change of sowing dates
	Reduced soil cultivation
	Efficient use of protective snow hedges
	Introduction of windbreak systems to prevent snowdrift, reduce wind gusts and increase soil moisture
Adaptation measures to droughts	Cultivation of crops under irrigation systems
	Increase of water use efficiency with existing irrigation systems when there is not enough water in the source/channel/well
	Multi-purpose accumulations for water supply
	Use of drainage channels for irrigation
	Introducing and growing varieties/hybrids resistant to drought and heat
	Installation of shade nets to save water and lower the temperature
	Erection of windbreak belts to reduce wind erosion and soil drying and ensure uniform watering
	Agricultural insurance against drought damage
Adaptation measures in livestock production	Cooling barns, poultry houses and other buildings for animals
	Provision of water for animals
	Cooling and oxygenating water in fishponds
	Provision of alternative feed due to reduced grazing
	Use of indigenous breeds because they are better adapted to the environment
	Increasing veterinary monitoring for the emergence of new diseases

Mitigation of the effects of climate change needs the engagement of the entire community on a strategic level, including government, local authorities, social organisations, insurance companies, specialized planning and design agencies, IT and education experts, scientists, advisors, agricultural organisations and agricultural producers themselves. Each of the above-mentioned stakeholders has an important role to increase adaptive capacities, and their continued cooperation is the basis for reducing the risks to agricultural production to a minimum. There is a series of measures to be used to provide support to agricultural producers:

- Establish a central focal point for coordination and planning of adaptation measures;
- Support the development of climate change monitoring and the scientific sector;
- Plan and regulate territories, including the development of irrigation and drainage systems, erection of windbreak belts, etc.;
- Support the promotion of sustainable, environmentally friendly and energy efficient agriculture;
- Enhance agricultural producers' knowledge;
- Establish information sharing and early warning systems for agricultural producers;
- Develop and promote insurance schemes for agricultural land and crops;
- Encourage the establishment of agricultural producer associations and their networking with other sectors.

4.2. Irrigation as an adaptation measure

The development of agriculture together with climate change has brought about the need to restore irrigation systems and build new ones. Serbian Government is investing great efforts, not only financial but also technical, to expand irrigation systems to the extent possible. By 2015, irrigation systems were restored on 65,548 ha, and by 2018, on additional 32,000 ha, so currently irrigation is enabled on 87,000 ha on public land in Vojvodina, and on 700 ha in Negotin flatlands.

The strategic document [P.35] provides for the development of irrigation on additional 100,000 to 250,000 ha by 2034. In general, the Water Areas Bačka and Banat have the greatest water potentials, but also many areas that are under certain conditions appropriate for irrigation (brackish, impermeable soils, prone to water logging). The areas of Srem and Mačva are relatively rich with both surface and ground waters, but their use is limited, because of other users (water supply system), and is conditioned by the international character of the waterway. In the area of Belgrade, the main water resources are Danube and Sava rivers, which can in the first stage be used to catch around 15 m3/s, i.e. irrigation can be developed on around 14,000 ha. However, in the area of Barajevo, for example, where the hydrographic network is quite modest, with total waterway flow of only 1 m3/s, which is insufficient to supply water to the population, the development of irrigation will not be possible without ensuring water accumulation.

It is also similar with the areas of Toplica Region, South Morava and Šumadija, which have relatively modest water resources, and the quality of which, considering the size of the population in this area, is under significant threat. In these areas, water needs to be consumed rather sparingly, and possibilities to accumulate water and reuse processed waste waters needs to be considered in the long term.

Firstly, the recommended expansions of irrigated areas over the next 10-30 years (Table 12) relate to the areas under vegetables, potatoes, pulses and fruit. When it comes to field crops, special focus should be on the expansion of irrigation (up to 55,000 ha) for exported cultivars, in order to ensure stable exports, such as maize, wheat, sunflower, soybean and sugar beet, followed by alfalfa, oats, rye and barley (100-2,000 ha). Significant variations in yield due to drought and climate change can be seen in fruit production. It is desirable to expand irrigation to areas under fruits for export, such as apples, plums, pears, peaches, apricots, sour and sweet cherries and berries, just to ensure a stable yield, and much larger areas if processing and higher exports are planned. The expansion of irrigation for vegetables, such as onions, tomatoes, cucumbers, squash, watermelons, etc. is also important. Proposed areas for irrigation by 2030 are realistic, because by 2015, one-third of planned expansions was already realized.

Table 12: Recommendation to expand areas under irrigation (ha) by 2030

Region/cultivars	Vegetables, melons, strawberries	Potato	Beans and pulses	Raspberries, blackberries and other fruit	Field crops up to 20% increase	Total new areas for irrigation
Belgrade	2,405	205	115	26	306	3,061
Vojvodina	21,269	3,775	1,925	106	1,070	28,145
Šumadija and West Serbia	8,417	15,593	1,479	13,442	1,230	40,161
South and East Serbia	6,095	5,559	1,479	857	386	14,380
Total	**38,186**	**25,132**	**4,998**	**14,431**	**2,992**	**85,747**

If by 2050, irrigation systems were built on 174,000 ha, then 8% of the total arable land would be watered. It should not be expected that the entire area will be watered. Even though at first glance it seems these are small areas (a total of 86,000 ha), recommended for the construction of irrigation systems in the period of 10 years, these areas are significant from the perspective of irrigation development trends over the past years. During the past 5 years, irrigation of additional 33,000 ha was ensured, and proposed development projections are realistic, in line with the water management development, but clearly indicate it is necessary to intensify the irrigation development process. According to the reports [P.36], the costs of construction of irrigation systems in Serbia vary between 3,000 and 5,000 EUR/ha. Lower costs are certainly the result of using existing infrastructure (Dunav-Tisa-Dunav Canal), or because there will be no construction of large infrastructural facilities. However, if a damn was to be built to accumulate water for irrigation or reservoirs, costs would be considerably higher. By 2030, around 700 million USD, and by 2050, around 1.4 billion USD should be ensured for the envisaged development of irrigation.

4.3. Mitigation measures by draining

The efficiency of a network of channels is directly linked to the condition of the network. Only regularly maintained channels, at the level of designed profiles, can both meet the criteria and remain functional. Inadequate and insufficient maintenance of constructed systems, with a lack of funds necessary to perform functional works and regular maintenance, are the most important causes of poor functioning of the network of channels used for draining.

For the network to remain functional, the following dynamics of works is needed:

- Sludge should be removed from higher-tier channels once in ten years;
- Sludge should be removed from lower-tier channels once in five years;
- Normative for sludge removal in the network of channels shall be 0.1 m3/m`. Normative for sludge removal in streams shall be 0.1 m3/m`.
- Culverts and bridges need investments of 2.65% of the total investment for regular maintenance;
- Vegetation clearing should be done at least once a year by applying mechanical and chemical means;
- Needs for regular investments for the maintenance of pumping stations should be met based on long-term average investments for these needs.

The programme of works on maintenance of publicly owned water facilities for drainage is determined based on planned unit prices for the current year and analysis of the condition of facilities and needs to ensure the functionality of water facilities, which cannot be provided through regular maintenance (Table 13). Available resources, provided within the water management programme for water stream regulation and protection from adverse effects of waters, which in 2017 amounted to 1,220,333.00 RSD, are insufficient to complete maintenance works in the required scope, are not sufficient to repair new damages and cannot ensure efficient funding of flood defence measures. Even though considerable works on reparation were done after the flood events of 2014, the condition of protection and regulatory facilities with reduced scope of regular maintenance in 2016 did not ensure the required reliability in the conditions of high waters.

Development plans are completely aborted due to a lack of technical documents, notwithstanding recorded needs. This will also reflect on the preparedness to use funds from foreign sources, the amounts of which enable the realization of capital protection facilities. For these reasons, the risk of new floods and other forms of damaging effects of waters, has increased significantly.

Table 13: **Costs of regular and investment maintenance of publicly owned drainage systems by RS**

Water management area	Year	Regular and investment maintenance costs (RSD)	
		Realized	% of needed
Srbijavode	2015 2016 2017 2018 2019	246.108.292 152.076.725 334.818.620 498.950.287 395.000.000	27,9 17,3 38,0 56,7
Vojvodinavode	2015 2016 2017 2018 2019	2.676.133.245 2.272.727.273 2.226.000.000 1.606.039.699 1.645.000.000	59 58 60 46 42

Regular and investment maintenance of drainage systems is the most important adaptation measure used to preventwater logging, primarily at the level provided by normatives, which are current results show to be far below that.

Data on increased maximum values for 1-, 2-, 3- and 5- day precipitation imply that there will be excess water, and therefore needs for drainage will increase. Increased needs for the maintenance of the network of channels and all auxiliary network facilities (culverts, cascades, pumping stations, etc.) will arise not only because of increased extreme daily precipitation, but also because of other climate change effects (favourable temperature and moisture conditions with higher CO2 content will impact more abundant growth of weeds in the long-term, etc.). Data for the past five years (Table 13) show that the needs for regular and investment maintenance of the drainage system are at around 880 million RSD (PWA Srbijavode up to 3,914 million RSD (PWA Vode Vojvodine). Considering that numerous channels were designed and are used for two-fold purposes of drainage and irrigation, it is estimated that due to climate change, needs for maintenance will increase up to 10% by the end of the century.

4.4. Agrotechnical (and other) mitigation measures for field crop and vegetable production

4.4.1 Good agricultural good practices and technologies

The basis for mitigating the effects of climate fluctuations in field crop and vegetable production is the implementation of adequate agro-technical measures (Chart 11). They relate to crop rotation, soil cultivation, deep-loosening, choice of varieties (hybrids), sowing, plant nutrition, weed and pest control, irrigation, drainage and harvest.

Depending on the cultivar and agro-environmental conditions, these practices and technologies have their specificities. In regions with lower amounts of precipitation, varieties with shorter vegetative phases, for example, hybrid corns of FAO 300-500 maturity groups (100-125 days) [P.37] should be sown. In areas prone to high winds and hailstorms, wheat varieties with lower and firmer stalks should be grown. In case of droughts, soy seeds should be sown deeper (5 cm), and less densely, by 5-10% than usual [P.38]. Accordingly, good quality agrotechnics ensure high level of security and stability in the production of field crops and vegetables under climate fluctuations (Tab. 14).

Alternative agro-technical measures – With agricultural development, a whole new range of alternative agricultural technologies has been developed, to mitigate the effects of climate fluctuations in agriculture: soil conservation measures, mulching, growing cover and mix crops, agro-forestry, and other (Table 14). Measures that have proven to be useful in certain countries are being tested in our conditions, on our soils, cultivars and varieties. Numerous alternative adaptation measures are finding their place in field crop and vegetable production and they are more and more frequently used in the fields in the Republic of Serbia. It will take time to educate agricultural producers to implement these measures and verify their values in practice.

Table 14: Agricultural good practices and technologies as adaptation measures

Good agricultural good practices	Adaptation measures
Crop rotation	• Select appropriate crops • Avoid monocultures
Soil cultivation	• Plough harvest residues • Timely basic cultivation • Good pre-sowing preparation • Inter-row cultivation
Deep loosening	• Deep loosening of compact soil
Variety selection	• Purchase certified seed • Choose modern varieties adapted to climate conditions • Diversify assortment
Sowing	• Seed inoculation as needed • Timely sowing at appropriate depth • Adjust sowing density to climate conditions
Plant nutrition	• Soil analysis and calculation of necessary nutrient quantity • Optimum basic fertilization • Suitable initial fertilization and nutrition
Weed and pest control	• Combination of agro-technical, biological and chemical measures for weed, fungus, bacteria, viruses, insects and other pest control
Irrigation and drainage	• Irrigation according to plant needs using appropriate watering norms • Regular maintenance of drainage channels and systems
Harvest	• Timely and proper harvest

Alternative agro-technical measures	Description of measures
Conservation	• Reduced cultivation • Partial cultivation • No tillage (direct sowing)
Mulching	• Cover the soil using organic mulch
Cover crops	• Grow cover crops and green manure to improve soil qualities
Strip cropping	• Mix crops by sowing in alternating rows or strips
Introduction and diversification	• Introduce in production plant species that have not been grown before • Refine and use locally adapted plant populations and old varieties
Environmental field regulation	• Ecological corridors, insect habitats and belts
Agroforestry	• Grow crops between sparse tree rows

Many of these measures are applied in organic agriculture, which, in an environmentally sustainable manner, by using natural procedures and substances, helps reduce the use of non-renewable energy sources and gas emissions, thus representing an effective strategy for climate change mitigation. In recent years, various reduced cultivation variants have been applied, leaving some harvest residue on the non-cultivated surface layer of the soil, thus conserving moisture and increasing micro-biological activity. Mixed sowing of two or more crops enables greater stability and variety of production. Agroforestry represents crop growing between sparse tree rows, with their shadows protecting the crops from too much sun, increasing biodiversity, improving soil fertility and structure, and helping maintain good quality of ground waters.

Producers should be recommended areas for growing seed crops and separate them physically from lots used for growing mercantile crops. This is particularly important in seedling production and seed potato production, because these plants are very sensitive to plant viruses easily transmitted by insects in the field, and seedling material needs to be virus-free. It has been proven that there are no vectors on mountains higher than 1,000 m (e.g. Golija), or there are few, which is why the quality of produced seed potatoes is very good.

4.4.2 Agro-technical (and other) mitigation measures in fruit production

Regionalization of fruit production. One of the ways to overcome issues related to climate change is to study climate, orography and edaphic conditions in specific localities of our country. Based on these analyses, appropriate fruit species and their varieties should be recommended, which can give optimum results under such agro-environmental conditions.

- Support the development of climate change monitoring and the scientific sector;
- Plan and regulate territories, including the development of irrigation and drainage systems, erection of windbreak belts, etc.;
- Enhance agricultural producers' knowledge;
- Establish information sharing and early warning systems for agricultural producers;
- Encourage the establishment of agricultural producer associations and their networking with other sectors.

Agricultural good practices and technologies – This chapter presents adaptation measures that can be implemented directly by fruit producers and most important examples.

- Selection of species:
  - In areas with increased dangers of occurrence of late spring frosts (river valleys, basins, flatlands in Vojvodina), cultivate species that start vegetating late, such as apple, quince, raspberry, blackberry;
  - In regions with greater dangers of winter frosts (West Serbia, also terrains at higher altitudes) grow more resilient species (apple, sour cherry, red currant);
  - In regions with lower precipitation, grow species resilient to drought (North Vojvodina, South Serbia) (walnut, sour cherry, almond);
- Variety selection:
  - Grow sweet cherry varieties with crack-resistant skin because of sudden and heavy rainfall;
  - In flat terrains, where high temperatures prevent the development of additional colour, grow colourless varieties or varieties that easily gain additional colour;
  - In windy areas (Central and South Banat, Podunavlje), grow apple varieties with long stems;
- Choice of rootstocks:
  - In regions with low precipitation (North Vojvodina, Jablanica District), varieties should be grafted onto more abundant rootstocks;
- Soil cultivation methods:
  - Plant grass where there is danger of excess precipitation and where there is irrigation, as well as on inclined terrains to prevent soil erosion;
  - Clean cultivation on dry terrains, without the possibility for irrigation;
  - Apply mulch film;
- Construct irrigation systems;
- Install irrigation systems for frost protection;
- Install hail nets to prevent the effects of hail and fruit scorch. Hail nets reduce air temperature in the orchard by 1 to 3 oC [P.39], which has very positive effects on the most important physiological processes in the plant. In this way, the negative effects of expected increase in average annual temperatures can be reduced;
- Install belts in the direction of winds to reduce adverse wind effects.

4.4.3. Measures for the protection from pathogen spreading

Increase control of plant material sales in domestic and international trade to prevent entry and spread of pests, diseases and weeds:

- Establish special surveillance measures for vulnerable plant species (which is already being done in part, under the auspices of the Ministry of Agriculture, Forestry and Water Management);

- Conduct lab tests to establish the presence of certain and specific pathogens (viruses, bacteria and fungi);
- Monitoring of particularly harmful or potentially harmful species;
- Implement measures to eradicate and contain entered foreign pests, diseases and weeds;
- Continuous training of field experts in the area of plant protection on new species of pathogens and pests;
- Continuous training of agricultural producers on how best to avoid damages resulting from climate change.

4.4.4. Adaptation measures in livestock production and fishery

Some adaptation measures in livestock production and fishery for both animal well-being and reduction of gas emissions are the following:

- Catchment of water sources for watering livestock (catchment may be multi-purpose);
- Cool barns, poultry houses using irrigation systems, equip them with special sprinklers made for the purpose, the so-called foggers, which create fine, fog-like drops, and are widely used in countries with high air temperatures, like Mediterranean countries;
- Ensure shade for grazing cattle;
- Harmonize poultry breeding batches (avoid warmest or coldest parts of the year);
- Provide cattle feed, when grazing is impossible due to drought;
- Increase animal health monitoring;
- Refresh water in fishponds, when water temperature rises above the limit suitable for fish, by adding colder well water;
- Increased water oxygenation, due to higher oxygen consumption by aquatic flora and fauna;
- Voluminous feed for pigs should be supplemented with concentrate, in order to preserve digestive tract function and reduce gas emissions [P.40];
- Increase efficiency of livestock production, reduce mortality and improve health of animals to reduce gas emissions;
- Shorter stay of manure in the holding or in lagoons, composting, adequate and timely ploughing; apply slurry under subsurface irrigation system to reduce gas emissions;
- Genetic selection better adapted to climate conditions.

4.5. Opinions of agricultural producers and Agronomists about the importance of adaptation measures

According to literature sources, numerous methods for prioritizing measures of adaptation to climate change can be applied. Some are simple, such as the evaluation method, check list, approximation, while others are complex and include mathematical models or multiple-criteria decision analysis (MCDA). For the purposes of this study, the importance of presented adaptation measures was evaluated through the survey targeting agricultural producers and by applying MCDA based on experts' opinions. Detailed description of the model is provided [P.41; P42; P43].

Based on MCDA, 10 top measures are presented in Table 15. **The top ranked measure is Use of multipurpose accumulations for water supply**, followed by **Construction of anti-frost systems**, while **Agronomic measures** are ranked third. The first and third-ranked measures were identified as the most important ones both in existing studies implemented within the Serbia Climate Strategy and Action Plan (2015-2019) project, also using MCDA, with other experts participating in the evaluation of measures.

It is important to note that agricultural producers that participated in the survey also identified these measures as very important, although they thought the most important measures were **Growing crops under irrigation systems (and the construction of irrigation systems)**, followed by **Installation of hail net**s and **Agro-technical measure**s (Table 16). Considering that respondents from the entire country participated and that issues differ depending on the type of production, climate conditions and altitude, their opinions on the importance of adaptation measures also differ. Thus, for example, respondents from Belgrade region recognised irrigation as an efficient measure (3.4±0.35), as well as respondents from South and East Serbia (3.1±0.76). Vojvodina region attributes somewhat less importance to this measure (2.98±0.75), while respondents from the region of Šumadija and West Serbia see the least efficiency in irrigation. Such results correspond to the occurrence of drought in different regions [P.24].

Respondents coming from different regions in Serbia disagree on whether **mitigation of water logging** is an efficient measure in climate change protection. Respondents from the Belgrade region agree the most with the efficiency of this measure (3.14±0.49), and the least agreement comes from respondents from Šumadija and West Serbia (2.44±0.71). There is a statistically significant difference in the perception of efficiency of **adaptation to extreme climate conditions**, relative to the region, average land size, whether the person is involved in field crop production or not, whether the person is involved in fruit production and terrain characteristics. The following respondents agree that this measure is efficient more than other categories: respondents from Belgrade region and South and East Serbia regions (3.11), those with the smallest land plots (up to 10 ha) (2.96±0.61), those not involved in field crop production (2.98±0.68), those involved in fruit production (3.09±0.5) and those coming from mountainous areas (2.98±0.58). Thus, they highlight the importance of measures including also **Construction of anti-frost irrigation systems**.

We can conclude that experts and agricultural producers alike agree that these are very important climate change adaptation measures: Irrigation, Agro-technical measures, Use of multi-purpose accumulations for water supply, Use of drainage channels for irrigation, Installation of hail nets, Drainage and Improved practices for protection from water erosion. Other measures are equally important, but given lesser weight, and thus have second-rate priority for implementation.

Table 15: Ranking of mitigation measures by applying MCDA

Measure	Rank
Use of multi-purpose accumulations for water supply	1
Construction of anti-frost irrigation systems	2
Agro-technical measures (crop density, time of sowing, fertilization, etc.)	3
Use of drainage channels for irrigation	4
Restoration of wetlands, vegetation and reforestation to avoid floods/erosion	5
Construction of irrigation systems	6
Improved practices for protection from water erosion	7
Installation of hail nets	8
Growing crops under irrigation systems	9
Increased efficiency of water consumption with existing irrigation systems when there is insufficient water in the source	10

Table 16: The opinions of agricultural producers about the importance of adaptation measures

No.	Adaptation measure	Min.	Max.	Freq. min.	Freq. max.	Average	Variet.	St. dev.
1, 2	Growing crops under irrigation system (construction of irrigation system)	max.	4	5	76	**3,35**	0,67	0,82
3	Installation of hail nets	1	4	6	64	**3,21**	0,73	0,86
4	Increased efficiency of water consumption with existing irrigation systems when there is insufficient water in the source/channel/well	1	4	6	53	**3,06**	0,77	0,88
5	Agro-technical measures (crop density, time of sowing, fertilization, etc.)	1	4	4	39	**2,98**	0,63	0,79
6	Installation of shading nets to save water and lower the temperature	1	4	10	44	**2,94**	0,82	0,91
7	Use of multi-purpose accumulations for water supply	1	4	14	44	**2,87**	0,94	0,97
8	Use of high-yield varieties and hybrids in conditions where irrigation is applied (for more efficient water, nutrient and energy use)	1	4	8	37	**2,86**	0,76	0,87
9	Construction of systems for drainage and good system management	1	4	10	38	**2,85**	0,81	0,90
10	The selection of fruit varieties and rootstocks, selection of terrain	1	4	10	32	**2,82**	0,75	0,86

5.
CONCLUSION

Agriculture is an inseparable part of the environment, and anomalies that occur in nature, whether related to the weather, water or soil, impact all production cycles in agriculture. All segments of agricultural production will be more or less affected by climate change. The greatest impact will be on plant production, because of the duration of the growing cycles, which can last for several months, half a year, several seasons, several years or several decades. Direct impacts on livestock production are also possible (impact of extreme heat waves, lack of water and food), but they are more often indirect, visible in malnutrition, poor water quality, unfavourable breeding conditions, and similar.

Adverse impacts on plant and livestock production will also have an impact on food production, and irregularities in the supply chain with raw materials for the food industry will cause economic instabilities and social precarity. The recognition of all negative effects caused by climate change in agriculture and activities undertaken timely and at all levels (including the Government and all stakeholders), can help implement existing measures and potential strategies, also taking advantage of certain benefits.

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