Report on the impact of climate change on the AGRICULTURE sector, with proposed adaptation measures

ACTIVITY 3:
Proposed adaptation measures

Authors:

Prof. MirjamVujadinovićMandić, PhD, University of Belgrade, Faculty of Agriculture
Prof. ZoricaRanković-Vasić, PhD, University of Belgrade, Faculty of Agriculture
Prof. Marija Ćosić, PhD, University of Belgrade, Faculty of Agriculture
Prof. Aleksandar Simić, PhD, University of Belgrade, Faculty of Agriculture
Prof. DejanĐurović, PhD, University of Belgrade, Faculty of Agriculture
Prof. ŽeljkoDolijanović, PhD, University of Belgrade, Faculty of Agriculture
Prof. Ana VukovićVimić, PhD, University of Belgrade, Faculty of Agriculture
Assistant Prof. LjubomirZivotić, University of Belgrade, Faculty of Agriculture
Assistant Prof. Dragan Stanojević, University of Belgrade, Faculty of Agriculture
MSc in Agricultural Engineering AleksaLipovac, University of Belgrade, Faculty of Agriculture

List of Abbreviations

ABA	Abscisic acid content
CI	Cool night index
DI	Dryness Index
FAO	Food and Agriculture Organization of the United Nations
HMN	Median value of the irrigation hydromodule
HI	Huglin Index
IDP	Irrigation and Drainage Paper
IPCC	Intergovernmental Panel on Climate Change
NIWR	Net Irrigation Water Requirement
NNN	Net Irrigation Rate
RCP	Relative Concentration Pathway
RH	Relative Humidity
RP	Reference Period
TB	Base Temperature
THI	Temperature Humidity Index
UNDP	United Nations Development Programme
WIN	Winkler Index

CONTENTS

1. Adaptation measure: Improvement of agrometeorological services

The Department of Applied Climatology and Agrometeorology within the Sector of the National Center for Climate Change of the Republic Hydrometeorological Institute of Serbia (RHMZ) has the authority to conduct agrometeorological observations, collect, control, analyze and store them, monitor agrometeorological conditions, issue regular and extraordinary agrometeorological information, forecast and warnings. Agrometeorological observations refer to soil temperature, evaporation, evapotranspiration and phenological data, and such a monitoring program is currently carried out at about 30 agrometeorological stations of RHMZ in the territory of Serbia. Soil moisture measurement is not currently covered by this program, although such data is of great importance for crop production.

In recent years, The Agricultural Advisory Service of Serbia (PSSS) has set up a number of automatic agrometeorological stations throughout Serbia, but their exact number is not publicly available.

Meteorological and agrometeorological observations are among the key information in agricultural practice. Due to the great spatial heterogeneity of these parameters, and especially those related to the soil (soil temperature and humidity) and the amount of precipitation, it is necessary to continuously increase the number of relevant observation stations (**Activity 2: Improving the agrometeorological monitoring system**), but also the integration of RHMZ and PSSS databases (**Activity 1: Development of an integrated database for agrometeorological observations**), in order to make the most of existing resources. These activities are in line with Priority area 6 (adaptation and mitigation of the effects of climate change) of the Strategy of Agriculture and Rural Development of the Republic of Serbia 2014-2024 (Official Gazette of RS 85/2014).

RHMZ regularly prepares and publishes seven-day, ten-day and monthly agrometeorological newsletters, as well as annual agrometeorological analyses. The newsletters mainly present meteorological and agrometeorological data and indices in the territory of Serbia observed during the past period, as well as their deviation from the climatological normal, drought monitoring information (Standardized Precipitation Index - SPI, Palmer Z Drought Index - Z Index, and Palmer Drought Strength Index - PDSI), weather forecast for the next ten days or a month in the text form, evapotranspiration forecast in the next ten days, as well as the SPI index forecast based on observed data and a ten-day weather forecast. As part of the second product, the Newsletter of Early Announcement of Climate Extreme Phenomena and Anomalies, issued by the Department for Climate Monitoring and Climate Forecasting RHMZ, contains, among other things, the SPI index category calculated on the basis of observed data and monthly weather forecast, but these data are not included in agrometeorological newsletters.

Given the availability of a large amount of information from numerical forecasts (from short-term, medium-term and long-term forecasts to climate simulations), many of which are already operationally calculated within RHMZ, agrometeorological newsletters could be improved with new products, primarily from monthly and seasonal forecasts (**Activity 3: Improvement of agro-meteorological weather forecast products**). The products would relate to the probability of drought, high rainfall, extremely hot or cold days, probability of frost in critical phenophases of sensitive agricultural crops, forecast of the sum of active or effective temperatures for relevant base temperatures, etc. Such information, with adequate explanation, education and training of agricultural advisors and farmers themselves (**Activity 4: Training of agricultural advisors on climate change and new forecasting products**) would significantly improve long-term planning within the agricultural production, contribute to raising awareness of the impact of climate change on agricultural production and increase the resilience of agriculture to weather risks and extremes associated with climate change.

2. Adaptation measures – Water and soil sector

Effective adaptation measures require a comprehensive and dynamic legal, professional-scientific and institutional approach covering different levels of problems and issues[1]. Climate change adaptation measures in the water and soil sector are singled out within the following five groups:

1. Irrigation
2. Revitalization and reconstruction of the existing canal network
3. Sustainable land use
4. Natural measures
5. Wastewater treatment

2.1. Irrigation

Measure description:

Irrigation is a measure of adaptation needed at the national level. Irrigation water needs and availability vary by districts (Figure 1). They depend on the demand of the atmosphere for water, amount of effective precipitation, plant species, precipitation distribution, soil characteristics, relief characteristics, as well as the total amount of available water, but also on whether man efficiently manages water resources.

1 Howden, S.M., Jean-François, S., Tubiello, F.N., Chhetri, N., Dunlop M., Meinke H. 2007. Adapting agriculture to climate change. Proceedings of the National Academy of Sciences of the United States of America.

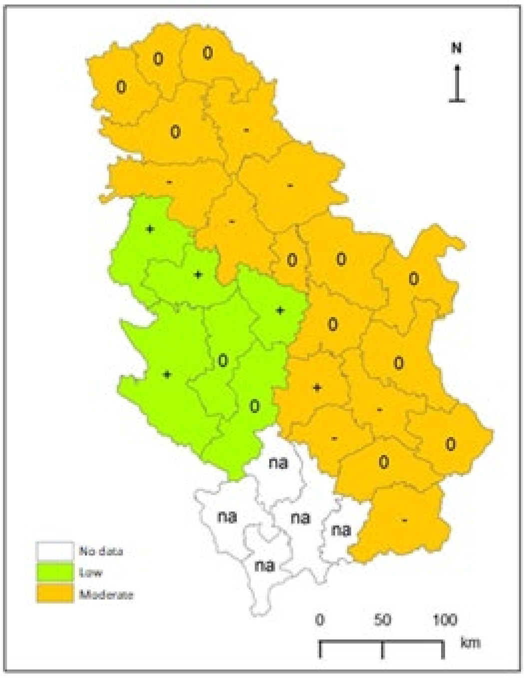

Figure 1. Shortage of water for irrigation risk

Each irrigation system is characterized by certain water losses. Water losses occur during the capture of water from various water sources, during the transport of water to the floodplain, during the redistribution of water on plots, as well as during the uptake of water by plants. If we ideally assume that each of these efficiencies is 90%, then the overall efficiency of such a system would be 65.6%. In real situations, these efficiencies are even lower, as is the overall efficiency of an irrigation system. In order to solve these problems, it is necessary to apply adaptation measures for each of these efficiencies. Measures to improve the first two efficiencies relate to the proper design and maintenance of irrigation systems, while measures to improve the other two efficiencies relate to the sustainable management of irrigation systems. According to the data, it is estimated that about 3% of arable land in Serbia is irrigated, which is a very small area compared to other European countrie[2]. Also, from the aspect of adaptation of cultivated plants to drought and predicted climate change, these data are worrying. The current potential for irrigation is not well used. Only with the dual-purpose canals of the Danube-Tisa-Danube hydro system in the area of Vojvodina, there is a possibility for irrigation of over 500,000 hectares. Despite this, only 30,000 hectares are under irrigation systems. There are also many irrigation systems that have been built but are not used because they have been devastated over time.

Rational management of irrigation systems means that the cultivated plants are supplied with the optimal amount of water for irrigation at precisely defined intervals and in a manner which least degrades soil and groundwater. Excess water for irrigation leads to consequences on plants, soil and groundwater. Plants suffer from excess water and their fruit quality decreases. Excess water for irrigation leads to the disruption of soil structure and leaching of nutrients from the soil. By disrupting the structure of the soil, the characteristics of the soil can be degraded irreversibly. Flushing of nutrients contaminates groundwater. All this is reflected in the economic

2 Census of Agriculture, 2012

profitability of investments in agricultural production. The goal of sustainable agricultural production should be to optimize the applied quantities of water and fertilizers, which, in addition to economic, also has environmental significance.

Irrigation as a measure of adaptation can also be achieved in conditions of the defficiency of water for irrigation by applying *deficit irrigation* or irrigation according to the critical needs of plants (*supplementary irrigation*). These irrigation methods increase the efficiency of water use in agriculture in conditions of water shortages, and they can be used in the optimization of agricultural production and in conditions of sufficient water. Rational use of water in intensive agricultural production, among other things, to measure the amount of water used for irrigation. Determining the optimal amounts of irrigation water is determined by various methods, but there are also frequent cases when this problem is tackled lightly and the amount of water is exaggerated, which is not good in the predicted conditions of climate change. For the needs of designing irrigation systems, a denser network of meteorological stations is missing, from which data on the values of climate factors would be obtained. Also, in the Republic of Serbia, there is a lack of agrometeorological stations that would be at the service of agricultural producers for *real-time irrigation scheduling*, which would lead to improvements in the irrigation sector.

Estimated damage:

Irrigation as a measure is not only aimed at raising the yields of cultivated plants, but also to make agricultural production more stable. Damages in agricultural production without irrigation vary from year to year. In some years, yields are reduced by 10 or 30%, and in some years there may be a drought that can reduce the yield by up to 50-80%. Damage in agricultural production with irrigation is less related to cultivated plants, but more to soil and groundwater, which can have great negative effects. Damage can be both short-term and long-term, especially if the soil is degraded.

Jurisdiction and indicators:

It is necessary for the Agricultural Advisory Services of Serbia (PSSS) to act in two ways regarding the adaptation measure of irrigation.

1. It is necessary to acquaint agricultural producers with the advantages of this adaptation measure, to enable them to easily apply for subsidies for digging wells and designing irrigation systems launched by the Agricultural Land Administration and provincial secretariats.
2. Then, through PSSS, train agricultural producers in the form of workshops, in order to acquire the necessary knowledge for the rational management of irrigation systems. In this manner, the efficiency of water use, water productivity will be increased and the most economically justified yield will be obtained, while preserving the soil.
3. PWMC to plan regional irrigation systems, where water placed under appropriate pressure would be delivered to each interested agricultural producer with a certain fee for the use of irrigation systems.

4. The Ministry of Agriculture, Forestry and Water Management, the Directorate for Water Management Land and the Provincial Secretariats to increase the amounts for subsidies for digging wells and installing irrigation systems. In addition to financing the measure, it is necessary to simplify the procedure and finance the measure in advance.

The current state of PSSS staff is such that they employ water and soil engineers to a small extent. Each PSSS should have an employed irrigation and soil engineer in charge of liaising agricultural producers with the institutional, scientific and professional sectors in the field of irrigation and sustainable soil management.

Indicators for this adaptation measure are the total area under irrigation and the amount of water used in irrigation on a seasonal basis. Total areas should grow but their planned growth should be monitored by measuring the amount of water used. This quantity should be rationally justified by the water user. The indicator can also be the share of employed irrigation and soil engineers in public institutions.

2.2. Revitalization and reconstruction of the existing canal network

Description of measure:

The canal network in Serbia consists of about 30,000 km of primary, secondary, tertiary, and lower-order canals. The largest part of the network is located in the area of Vojvodina (22,000 km), and they regulate the water level on almost 99% of the surface. As noted, these are mainly dual-purpose canals, whose main purpose is drainage with great potential for use and irrigation. Currently, drainage systems regulate groundwater levels to a good extent and provide good conditions for agricultural production.

For the system to function well, it is necessary to maintain the main canals, canals receiving water, canals in drainage systems on forest land, then repair units at pumping stations and rehabilitate buildings, remove plant vegetation to increase the effect of drainage.

The biggest challenge in maintaining the system is the removal of plant vegetation in the canal zone. The canals are often neglected, overgrown with herbaceous vegetation and muddy, which leads to a reduction in the hydromodule of the drainage system, which makes the system less and less efficient from year to year.

Data:

The parameters required to monitor the condition of the canal network are regularly monitored and are publicly available.

Estimated damage:

Damage due to the failure to maintain the canal can be direct and indirect. Direct ones occur due to the reduction of the efficiency of the system, which leads to an increase in groundwater levels, which currently affects cultivated plants and leads to a decrease in yield, and in the long run leads to soil degradation. Indirect damages refer to the impossibility of using the canal for other purposes. Due to the failure to maintain the canal, we are prevented from using it for irrigation, then, due to the vegetation, the quality of the irrigation water itself changes. The capacity of navigable canals is reduced and biodiversity is disturbed.

Jurisdiction and indicators:

Three public water management companies, *JVP Vojvodina vode*, *JVP Srbijavode*, and *JVP Šumadijavode*, are responsible for the maintenance and functioning of the canal network in Serbia. The indicator for this measure of adaptation should be the length of the cleaned canals and their condition in relation to the total length of all canals.

2.3. Sustainable land use

Measure description:

Serbia owns about 5 million hectares of agricultural land. The most common types of land on which agricultural production takes place in our country are chernozem, eutriccambisol, vertisol, humofluvisol, fluvisol and pseudogley, etc. These soils have different natural fertility and in their long-term use in agricultural production, the natural course of pedogenesis has been changed. In order for the soil to be used successfully in agricultural production, it is necessary to apply measures of sustainable soil management.

Sustainable use of soil and land includes the use of soil, water, flora and fauna for the production of goods that should meet the increased needs of humanity in a manner that would maintain the productive potential of these resources and maintain their functions in the environment. Sustainable soil management means measures that are adapted to the current bio-physical and socio-economic conditions in an area, and which aim to preserve, conserve and restore degraded natural resources and their ecosystem services.

In agricultural production, man exerts pressure on the soil in various ways. In farming, fruit and vineyard, vegetable and livestock production, human impact is reflected through regular agro-technical measures. Soil cultivation, fertilization, irrigation, plant protection, harvesting, passing of heavy mechanization over the soil, removal of nutrients from the soil, trampling of the soil on pastures, affect the natural fertility of the soil. In order to maintain and increase the natural fertility of the soil, man must use measures of sustainable land management, the application of which often depends on the natural conditions and the quality of the applied measure, but also on the economic justification.

Measures of sustainable soil management are aimed at preserving the soil cover through measures of increasing organic carbon in the soil, measures of conservation of soil moisture, measures of protection of soil from erosion by water and wind, measures of conservation treatment, etc. Within each of these measures, there are several measures that can be applied, e.g. reduced cultivation or direct sowing, terracing or sowing grass, mulching or shading crops, manure fertilization or addition of other organic fertilizers ...

Lack of data:

There are no precise comprehensive quantitative data on the application of sustainable soil management measures, which are applied to a certain extent in the conditions of current agricultural activities.

Also, there are no precise comprehensive quantitative data on soil degradation: disturbance of water-air regime of soil, loss of organic matter, losses of soil by erosion by water and wind, soil compaction, chemical degradation of soil by pollution, acidification, flood consequences. Many of these types of degradation occur at the level of farms, and in the conditions of predicted climate change, they can occur in wider areas. Data may exist at the producer level. Many of these types of degradation have their own trends that develop very slowly, i.e. they have a long-term effect, which is difficult to recognize.

Estimated damage:

There is an irreversible loss of fertile agricultural land during the construction of settlements, infrastructure facilities, roads, factories ... In agricultural areas, the damage is usually of a long-term nature and it is very difficult to notice the initial drivers (causes) of degradation, and most often it is the non-rational use of land. The most important threats to land resources in Europe include soil erosion, soil compaction, loss of biodiversity, depletion of soil organic matter, soil contamination, hydrogeological risk, acidification and salinization[3].

Jurisdiction and indicators:

The Agricultural Advisory Service of Serbia (PSSS) can act in two ways on the use of sustainable soil use measures as a measure of adaptation to climate change.

1. Introducing agricultural producers to the advantages of these adaptation measures which improve and maintain the quality of soil and improve agricultural production in the long run. The state should recognize the importance of these measures and economically encourage producers to apply them.
2. Training of agricultural producers in the form of workshops should be carried out through PSSSs in order to acquire the necessary knowledge for sustainable soil management and justify the application of these measures.

3 Soil Atlas of Europe, 2005

The current state of PSSS staff is such that they employ soil engineers to a small extent, and if they are indeed employed, the emphasis is only on quantifying the soil fertility indicators for fertilization purposes. Each PSSS should have an employed irrigation and soil engineer in charge of liaising agricultural producers with the institutional, scientific and professional sectors in the field of irrigation and sustainable soil management.

Indicators for this adaptation measure are the successful implementation of these measures and their quantification on an annual basis that would follow their trend, with mutual monitoring of the condition and the quality of soil.

2.4. Natural measures

Measure description:

Technical flood protection measures such as embankments and dams in the context of climate change cannot adequately protect the protected area. In order to prevent floods or at least mitigate them and reduce their damage, it is necessary to reach for new solutions. Natural Mmeasures of NBS (*Nature based solutions*), and within them natural water retention measures (*Natural Water Retention Measures*) can be a good solution for mitigating the flood wave and reducing damage in agriculture and other sectors of the economy[4].

Measures that can be applied in agriculture are various: change of the manner of using the soil, crop rotation, afforestation of borders, formation of storages, conservation treatment systems, water retention pools, return of old meanders, natural retentions, etc.

This set of measures would slow down runoff, retain more water in the soil and reduce the risk of erosion, improve water infiltration into the soil and water capacity of the soil, etc.

Lack of data:

-

Estimated damage:

Flood damage affects agricultural production and infrastructure, such as roads, bridges, embankments, backyards, etc. Damage can be short-term and long-term. Regarding short-term damage, a drop in the yield of agricultural species of 20-100% for all crops is meant. However, a great danger is posed by damages that are reflected over a longer period of time, such as a decrease in soil fertility and the complete impossibility of using it. If certain plots need to be excluded from agricultural production for a certain period, the damage is almost immeasurable.

4 http://nwrm.eu/

Responsibility:

Measures need to be implemented at the state level. When accessing NBS measures, it is necessary to have an agreement between representatives of the Government, state policy and landowners, as well as other stakeholders. Most of these measures can result in immediate damage to landowners, so the introduction of compensations is necessary in order to reach agreements. These measures can only be used in the Integrated Approach to Water and Soil Resources Management. The indicators for this adaptation measure are the applied measures on an annual basis and all the necessary information on the damage caused by the floods.

2.5. Wastewater treatment

Measure description:

In conditions of the shortage of water of good quality, water of "marginal quality" should be considered for use in agricultural production. "Marginal quality" waters can be defined as waters that have certain characteristics that can cause potential problems when used for certain purposes[5]. The use of communal water carries with it risks to human health while the use of brack water carries with it risks of soil degradation. These facts indicate that if we want to use these waters in agricultural production, it is necessary to apply certain treatment measures on them and in this manner monitor their quality. The application of these measures reduces water pollution, saves the use of good quality water, and uses large amounts of plant nutrients, especially phosphorus and potassium, found in these waters.

Lack of data:

Insufficient quantity and quality of effluent data.

Estimated damage:

The damage is based on the non-rational use of water resources. Discharge of these waters without treatment into watercourses disturbs the flora and fauna of watercourses, pollutes water resources and changes the quality of existing watercourses, leads to accelerated processes of eutrophication of water resources. These damages can occur in a short period of time, e.g. heavy metal pollution, or over a long period of time, e.g. eutrophication processes.

Responsibility:

At the national or local self-government level, wastewater treatment and reuse must be subsidized. The indicator for this adaptation measure is the amount of treated water used in irrigation.

5 FAO, 1985

3. Adaptation measures in fruit growing

3.1. Adaptation measures from low temperatures in fruit growing

The biggest problem related to low temperatures is the late spring frost occurring after vegetation, when certain organs (mainly flower buds) can be damaged. Depending on the stage of development of the flower bud, the critical temperatures range from -6, -7oC in the mouse-ear phase, -4, -5oC in the phase of pink buds, to -2, -3oC in the flowering phase.
In addition to the values of the lowest temperature, the duration of frost, relative humidity during frost, wind, etc., are also important. The most sensitive are the species that start early with vegetation (almond, apricot), then peach, cherry, plum, strawberry, cherry, pear, apple, quince, raspberry, blackberry.

By the selection of species, we can significantly reduce the negative effect of late spring frost in regions where it occurs more often. Currently, the lowest risk of late spring frost occurs in the territory of Vojvodina, and in the near future there will be no increase in the risk of frost in these localities (Figure). In the central, western and southern parts of Serbia, the risk of frost is high, with a tendency to increase in the future. This is especially true for species that start earlier with vegetation.

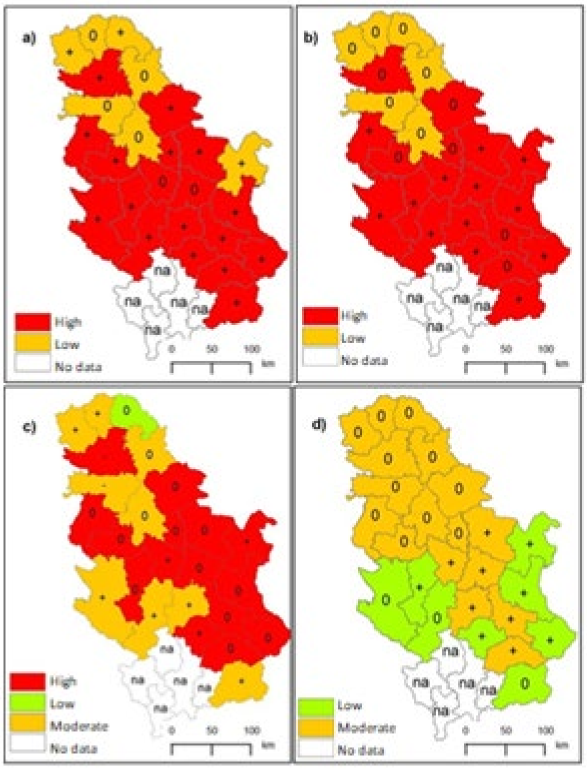

Figure 2. Frost risk depending on the species and location. a - almond, apricot, b - peach, cherry, c - plum, strawberry, cherry, d - pear, apple, quince, raspberry, blackberry.

There are also differences between cultivars. The Carmen pear cultivar is more sensitive to frost than the Vilijamovka cultivar. The Idared apple cultivar and all cultivars from the Red Delicious group will suffer more from frost under the same conditions compared to other apple cultivars. With plums, the "Čačanska rana" and "Prezident" cultivars are more susceptible to frost than "Čačanskarodna" and Stanley. In apricot cultivars, "NS 4", "Ruža" and "Novosadskarodna" bloom later than other important cultivars. In walnuts, the "Gasenheim", "Novosadskakasna" and "Rasna" cultivars start later, and are more resistant to frost.

Late spring frosts can be caused by radiation during quiet and clear nights (most often when clearing occurs immediately after the cool and rainy period). This frost is characterized by a short period of duration (mostly before dawn), it is of a local character (it most often occurs in valleys, bays) and the lowest temperatures occur just above the ground. Flowers in the lower parts of the tree crown mostly suffer from this frost.

Another way of late spring frost is by convection, i.e. the penetration of cold air masses. These frosts cover larger areas, can last longer and it can happen that temperatures at higher altitudes are lower than at the ground level.

The most important direct measures that can be applied in order to prevent the harmful effects of late spring frost are:

Protection of fruit trees with artificial rain (dew) is applied mainly in larger plantations and is based on the dew of flower buds, flowers or just sprouted fruits in the critical period when the air temperature drops below 0oC. Due to the effect of frost, water droplets that reach the plant turn into ice, releasing heat, which heats the tissue under the ice and does not allow damage to occur.

In this manner, protection against frost reaching -8oC can be achieved. It is very important that sprinkling lasts continuously while there is the effect of frost, so the main problem when using this protection system is the provision of a sufficient amount of water. For the successful operation of this system, it takes 40 m3 of water per hour per ha. Which means that for the protection of an orchard of 10 ha and if the frost lasts 5 hours, it is necessary to provide 2,000 m3 of water. For this reason, artificial accumulations are usually made in the orchard itself, from which the entire orchard is sprinkled with the help of strong pumps. This system is known as the "anti frost" system. The problem with the application of this system is the large wetting of the soil after the completion of its work.

Table 1. Criteria for prioritizing frost protection with the help of sprinkling

Criterion	Value
Efficacy	4
Cost effectiveness	3
Applicability	5
Urgency	4
Multifunctionality	2

Protection of fruit trees by heating is mainly used in smaller orchards. Devices used for this purpose can be stationary or mobile. In our country, mobile devices have found greater application, i.e. machines consisting of the heat source (usually gas cylinder) and a fan emitting warm air into the outside environment. These machines are usually pulled by a tractor through the orchard and it is necessary for them to pass through the same part of the orchard every 10-15 minutes, in order to constantly mix the air and at the same time raise the temperature, while reducing the relative humidity. One machine is enough for a plantation area of up to 5 ha, where it can raise the air temperature in the plantation by 2 to 3oC, as well as to reduce relative humidity. These machines are known as "*frost busters*". The protection of fruit trees by smoking is based on the burning of various materials (usually wet straw), so that smoke generated on this occasion could prevent heat from radiating from the ground layers of the soil. In this manner, the air temperature can be raised by 1 to 2^{o}C

Table 2. Criteria for prioritizing frost protection with hot air heating

Criterion	Value
Efficacy	3
Cost effectiveness	4
Applicability	5
Urgency	4
Multifunctionality	2

Protection of fruit trees by mixing air is applied when frost is formed by radiation during quiet and clear nights, i.e. when the difference in the temperature of the ground layer of air and the air at a height of 5-10 m is significant. Various fans or helicopters can be used for this purpose (Figure).

Table 3. Criteria for prioritizing frost protection with the help of air mixing

Criterion	Value
Efficacy	2
Cost effectiveness	3
Applicability	4
Urgency	4
Multifunctionality	2

3.2. Measures of adaptation from high temperatures in fruit growing

Late-ripening species (apple, pear, quince), as well as species that are characterized by black fruits (blackberry, black currant, blueberry), have the greatest sensitivity to high temperatures during ripening, so these species should be avoided in regions where periods of high temperatures occur frequently (Belgrade region, southern Banat, central Serbia. The lowest risk of high temperatures will occur in the Zlatibor region and Raška (Figure 3). In other regions, the risk of high temperatures will increase permanently.

Burns most often occur in July and August, when the air temperature exceeds 30°C and most often after a period of cold and cloudy weather. The temperature of those parts of the fruit that are directly exposed to sunlight in relation to the air temperature can be from 5 to 15 degrees higher. How much the fruit will be warmer in relation to the air temperature depends on a number of factors such as the intensity of solar radiation, wind speed, intensity of transpiration, air humidity, size of the fruit, etc.

In addition to direct factors (temperature and light), indirect factors such as relative humidity, wind, fruit acclimatization, variety, applied aids and agrotechnical measures - direction of rows, crown shape, plant height, summer pruning, irrigation, fertilization, anti-hail nets have a great influence on the degree of burns and how much damage fruits will undergo.

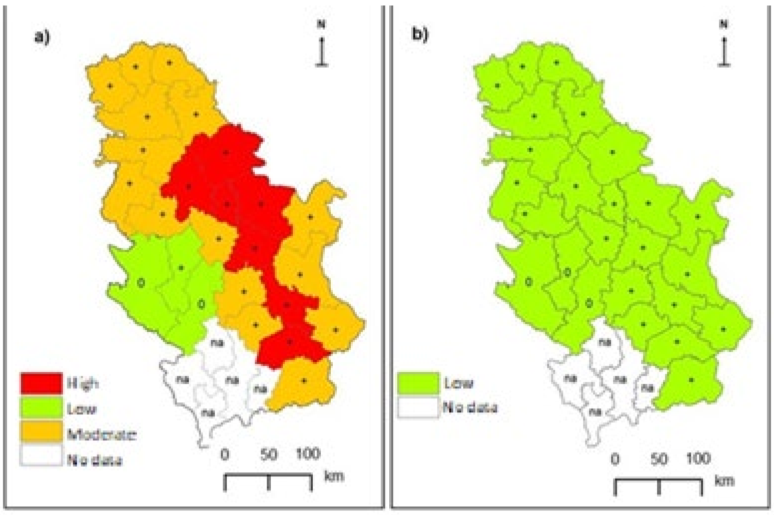

Figure 3. Risk of high temperatures depending on the species and locality. a - apple, pear, quince black currant, blueberry, blackberry, b - peach, plum, sour cherry, cherry, apricot, almond, raspberry, strawberry

High temperatures before harvest slow down the development of complementary color in colored varieties. Measures that can be applied in order to reduce the consequences caused by this environmental factor are the selection of the position (north side), installation of shading nets (usually anti-hail nets), grassing in the inter-row space, sprinkling plants with water.

Table 4. Criteria for prioritizing protection against high temperatures with the help of shading nets

Criterion	Value
Efficacy	3
Cost effectiveness	5
Applicability	5
Urgency	5
Multifunctionality	4

3.3. Measures of adaptation from hail and disasters in fruit growing

Hail can cause significant negative consequences for the fruit. Economically, the greatest damage from hail occurs with species whose fruits are primarily intended for fresh use. Species that ripen later are exposed to the potential effects of hail for the longest time, so the damage can be greater. As for the locality, the lowest risk of hail occurs in the north in the regions of western and central Bačka and northern and central Banat. The greatest risk from hail is in the Zlatibor region, as well as in the Moravica, Raška, Pomoravlje, Jablanica and Pčinja regions. On the entire territory of Serbia, the risk from hail will increase in the future (Figure 4).

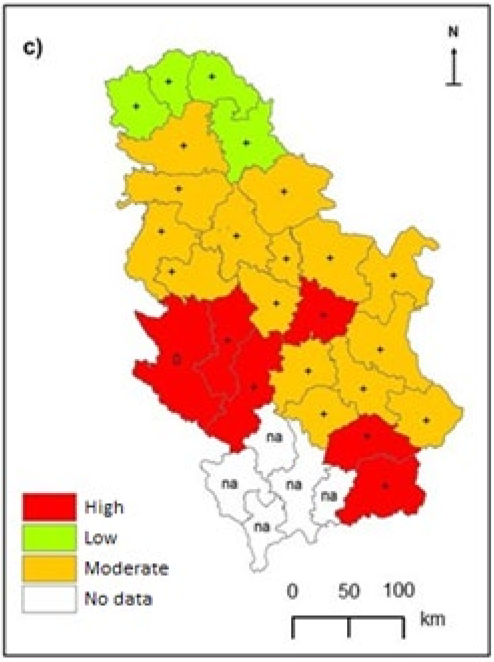

Figure 4. The risk from hail depending on the location

The most effective measure of protection from hail is the installation of anti-hail nets. These nets not only protect from hail but can also significantly reduce the negative impact of high temperatures. In our country, black nets are most often used, which are very long-lasting and mostly prevent the negative effects of high temperatures.

In addition to the installation of anti-hail nets, measures to mitigate the effects of hail are the use of anti-hail rockets, as well as insuring fruits from the loss of quantity and quality at insurance companies.

Strong winds can create big problems in fruit production, which usually leads to fruit loss. This is especially characteristic before harvest. Measures to combat this environmental factor are the planting of wind protection belts, cultivation of varieties that have a longer stalk and the treatment of fruit with synthetic auxins before harvest in order to prevent their decline. Strong stormy winds can in some cases cause both trees to fall and break. This is especially characteristic if weakly variegated bases are used in the orchard (M9 for apples, MC for pears, etc.). Measures to combat strong stormy winds are the planting of wind protection belts, planting of rows in the direction of the dominant winds and the installation of rests made of poles and wires.

4. Adaptation measures in viticulture

Measures for adapting viticulture to climate change at the global level are: moving vineyards to higher altitudes, natural shading of vineyards (cultivation on north-facing sides, setting up nets), adequate protection against diseases and pests due to more frequent adverse weather conditions, adequate defense against extreme events (droughts, floods, installation of anti-hail nets) and the appropriate selection of assortment. Appropriate agro and ampelotechnical measures such as tillage and pruning can also be applied in vineyards with the aim of mitigating negative extreme events in the appropriate phenophases of grapevine development. The planning and implementation of adaptation measures in a particular wine-growing region or vineyard depends on the local impacts of climate change.

4.1. Adaptation to high temperatures during the grapevine vegetation season

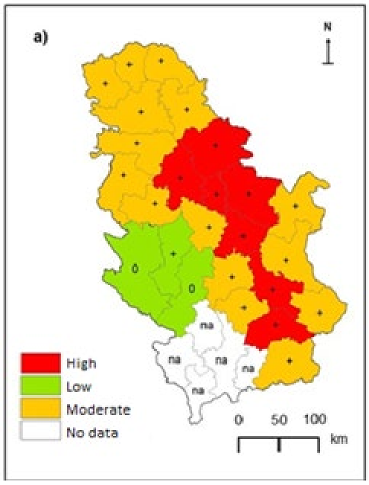

Figure 5. Risk of high summer temperatures in vineyards in administrative regions in R. Serbia

The tendency of increasing temperatures during the vegetation period in the summer months (grape ripening period) is projected for the regions of central, southern and eastern Serbia where the risk is assessed as very high (Figure 5). Temperatures over 30 and 35oC are especially risky, which were discussed in previous reports. The selection of the position, use of shade nets, monitoring chemical parameters in the bunch during ripening, shifting the harvest date are just some of the adaptation measures that must be observed during intensive viticulture production, in order to obtain quality grapes and wine.

4.2. Measures of adaptation from late spring frost in viticulture

Protection against late spring frost can include various measures, which can be divided into: passive and active.

Passive measures include various preventive measures that can be planned before the planting, but also during regular grape production. The choice of an adequate position is one of the very important measures that can prevent various negative effects on the grapevine, and thus reduce or eliminate low temperatures at the beginning of the vegetation. It is recommended to avoid planting in places where "cold air lakes" (foothills) are formed. The air temperature in these places, as well as on the tops of hills, is lower than on the slopes over which the cold air flows and passes without holding back. This is why the choice of gentle slopes is one of the important segments of raising a new vine plantation.

One of the measures that can also be applied and controlled is the choice of grass cover and the method of grassing. This agrotechnical measure can be carried out only in conditions with a sufficient amount of precipitation. In vineyards where the grass cover is set as permanent, solar energy accumulates less on the surface of the soil and therefore the risk of frost is higher. The reduction of the grass cover (grassing of every other row), setting of grass cover as temporary or other types of soil management that do not include the grass cover is one of the measures to fight late spring frost in regions where this danger exists. Controlling the moisture content in the soil can also provide protection against low temperatures during the period of starting and activation of sprouts. Wetter soils accumulate more heat than extremely dry soils. Wet soils during the night have the ability to heat cold air at the surface for a longer time and thus reduce the risk of frost. Optimum irrigation can sometimes be an adequate response in the months without precipitation preceding the onset of frost.

Active measures include changing the microclimatic conditions in the vineyard and consist of adding or preserving heat and mixing air. In vineyards, heaters on different types of fuel can be used, which serve to increase the air temperature to the limit where there is no danger of frost. Wind machines that have the role of mixing the air in some localities can be an adequate response in reducing the danger of low temperatures in the spring. These measures are not the most popular in vineyards in Serbia, so sprinkling through irrigation systems can also be used. Sprinkling creates ice scum on sprouts, which serves as an insulator, because during the formation of a thin layer of ice, the latent freezing heat of the water that heats the sprout is released.

Investments in the installation of irrigation systems are significant and can be applied where there are springs and possibilities to bring water to the vineyard.

It is recommended that measures of adaptation to low temperatures during the vegetation season be carried out in regions where this danger is very pronounced. High risk with a tendency to increase in the future is in Bor and Toplica districts (Figure 6) where adaptation measures must be applied. Also, in all other districts according to the availability of resources for this measure.

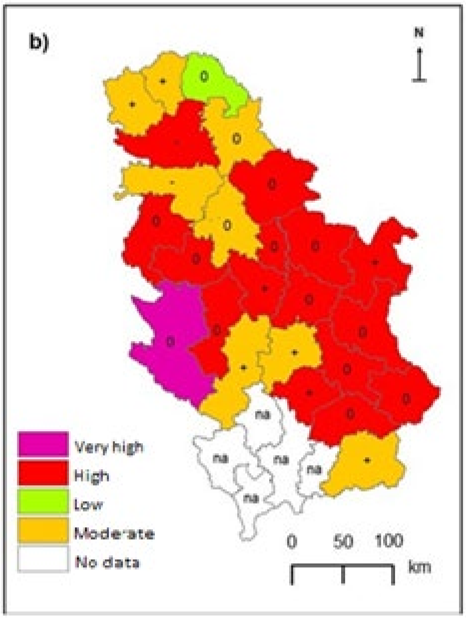

Figure 6. Risk of late spring frost in vineyards of different administrative regions in the Republic of Serbia

4.3. Measures of adaptation to hail in viticulture

Hail is extremely dangerous in viticulture, because for various reasons using anti-hail nets in the vineyards in the Republic of Serbia is not part of practice. Damage from hail on the grapevine in one production year can be extremely large and cause a decrease in the yield and quality of grapes, sometimes the loss of the entire yield and its reduction in the following year.

In addition to the use of anti-hail rockets in breaking hailstorm clouds, on which for now fighting against hail relies on in the Republic of Serbia, which sometimes does not give satisfactory results, investments in the installation of anti-hail nets, as well as appropriate conditions when insuring orchards, must be of state interest.

High risks from hail with a tendency to increase are present in 5 administrative districts (Jablanica, Pčinja, Raška, Pomoravlje and Moravica) (Figure 7) where it is necessary for the competent state institutions to help winegrowers in overcoming this risk as easily and quickly as possible for damages in wine production to be as low as possible.

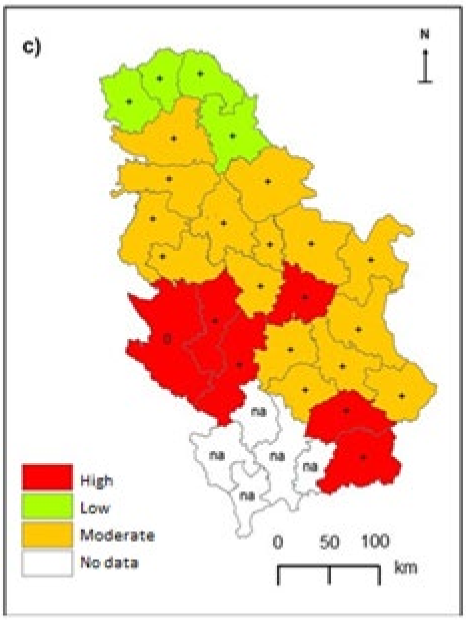

Figure 7. Risk of hail in vineyards in different administrative regions and the Republic of Serbia

4.4. Selection of the appropriate assortment

Climate change is already having a significant impact on grapevine growing and wine production. The benefits of the impact of climate change are the expansion of the area to higher altitudes and the reduction of the risk of winter frosts, while the risks of heatwaves, high summer temperatures and drought are increased. Due to increased climatic variability, i.e. due to the appearance of years that are very warm with extreme heatwaves, it is necessary to consider the resistance of current varieties to high temperatures, which often occur in combination with dry periods. In case of risk for growing certain varieties, it is necessary to plan and implement appropriate adaptation measures. In the current climate, although the risk of severe winter frosts is reduced, it still exists in some localities that indicate favorable conditions by other factors (for example, at higher altitudes or valleys with the possible occurrence of lakes of cold air during the winter). Such conditions are considered to withstand well the indigenous varieties (Prokupac, etc.), which survived in this area[6]. Consideration of the success of the implementation of the adaptation measure – the introduction of indigenous varieties in intensive production, would contribute to the authenticity of the approach to adaptation to climate change, and the implementation of this measure would give authenticity to the production of grapes and wine in the region and vineyard hills. Such varieties in the current climatic conditions can give a quality yield, and adapt easier to changes in their natural *terroir*. In the Program for the Development of Viticulture and Enology until 2031, the projected value of cultivation with autochthonous varieties is 20% of the total plantations (the Riesling variety is not included)[7]. This is very important because until 2019 there were only 8% of autochthonous varieties in Serbian vineyards.

Appropriate agrotechnical measures (pruning, irrigation, tillage, etc.) that can be applied to indigenous varieties are also one of the very important measures in their cultivation and achieving adequate and quality yield.

6 Project: Adaptation of the autochthonous gene pool of fruit trees and vines to the changed climatic conditions with the aim of achieving sustainable production. Ministry of Environmental Protection R. of Serbia, 2019

7 http://www.minpolj.gov.rs/download/program-razvoja-vinarstva-i-vinogradarstva-republike-srbije-za-period-2021-2031-godine/

4.5. Organic viticulture

As one of the ways to combat climate change and greenhouse gas emissions, should take a more significant place in the overall viticulture sector. The area of organic/sustainable production plantations in 2019 was 0.45% of the value, while the plan is for the projected value to reach 10% of the total plantations by 2031[8]. The use of appropriate vineyard plots for the construction of new vineyards according to the principles of ecological production, andalso the conversion of conventional vineyards into organic ones, can be important in preserving the environment and combating climate change.

4.6. Obstacles to the implementation of adaptation measures and suggestions/recommendations for improvement

- The main obstacles in the application of appropriate adaptation measures in viticulture are: lack of financial resources, high bank interest rates, poor infrastructure, insufficient availability of water sources in areas with higher altitudes, the problem of water supply at lower altitudes, lack of development of professional/advisory assistance, poor communication with local governments, ignorance of the effects of climate change on viticulture and wine sector (insufficient education), lack of appropriate meteorological data, poor communication with insurance companies (small percentage of insured plantations, inadequate damage assessment), etc.
- Recommendations for improving the situation are: capacity building (education of PSSS, local self-government and other relevant factors), different types of subsidies (line ministry, local self-government, different funds), production insurance, etc.

5. Adaptation measures in crop production

Given the many uncertainties, measures that would be applied in order to adapt to potential climate change shouldn't cause adverse effects on the soil, other crops or the population. In other words, it is desirable to apply such measures that would reduce the risk of climate change, but would also have other positive effects on society, economy, or environment.

It is necessary to plan significant investments for the development of scientific institutions and individuals that have already proven themselves in this area, but also for the development of regional centers and services that would enable the appropriate monitoring of local specificities. In this regard, it is primarily necessary to pay attention to the measures on the state level: development of monitoring of climate events and climate change and development of forecasting; development and adaptation of climate models for the territory of Serbia and its regions;

8 http://www.minpolj.gov.rs/download/program-razvoja-vinarstva-i-vinogradarstva-republike-srbije-za-period-2021-2031-godine/

applied research, characterization of conditions and development of new genotypes (varieties/hybrids) that are adapted to changed environmental conditions; research in the field of forecasting the occurrence of diseases and harmful species in changed climatic conditions, improvement and planning of preventive activities; development and adaptation of plant growing systems to new environmental conditions; research in the field of increasing the efficiency of agricultural production with the aim of reducing energy consumption by introducing and favoring new systems; improving the expansion and increasing the efficiency of the existing irrigation network and raising new ones in accordance with the possibilities; introduction of new species, varieties/hybrids that have not been grown in Serbia so far; regionalization of field production in new circumstances of changes in the system and represented species.Lazarević (2017)[9] points out that regionalization can contribute to the consolidation of the area and that it is a common practice in many countries because it precedes the implementation of rural development programs. Success in mitigating the effects of climate change in the future will be greater if we ensure the availability of meteorological data at the state level to all agricultural producers, by setting up meteorological stations that will be read and monitored by the local advisory service. Local governments (Departments of Agriculture) must work on educating persons who will assess the damage caused by natural disasters and effectively implement the system of records at the local level, and from this a national register should be made which will contain all data at all localities. However, the insurance of agricultural crops is the best solution. Currently, there is a company in Vojvodina that has a large digital coverage of the field, and it is enough for the producer to just report (electronically) the damage and the assessment, which the Banks or insurance companies recognize, will be ready in a very short time.

The second group of measures (**measures of a local character**) must focus on local specificities and relate to: the selection of new varieties/hybrids; changing the method of land cultivation in accordance with the type of the soil and the orientation of the farm; cultivation of new plant species that have not been grown in the given areas so far (e.g. quinoa at higher altitudes); erection and reconstruction of irrigation systems from local funds; changes in the soil and plant fertilization system; changes in optimal sowing dates for field species; application of various measures in order to increase biodiversity (mulching, cultivation of combined and cover crops, increasing the frequency of crops in the crop rotation); improvement of mechanization in accordance with the selected cultivation system (sustainable system, integrated/precision agriculture); a higher degree of crop insurance; association of farmers at the local level related to the specificities of the site, etc.

For the planning and implementation of these measures, it is necessary to provide advisory assistance to individual farmers, provide training for new cultivation systems and, of course, provide financial mechanisms from local and regional governments to support the implementation of adaptation measures. It is very important to improve further scientific research and monitoring of climate change at the local level because the choice of measures will largely depend on this.
Among the listed measures, either at the state or local level, some of them, mostly short-term adaptation measures, can be introduced without large investments, not to endanger the environment and can refer to several local areas or different agroecological conditions. These are changes in the optimal sowing dates, crop density, crop rotation, biological methods of protection

9 Lazarević, R. (2017): Kakosačuvatiiosnažitiresurse u poljoprivrediinaselu. Proceedings "Globalizacija glad u svetu, novetehnologijeinjihovuticajnaproizvodnjuhrane", Academy of Engineering Sciences of Serbia, Belgrade, 1-10.

and modification (reduction) of the tillage system. Then, the use of fertilizers, taking into account the needs of plants and the changed efficiency of fertilizers due to the changed climatic conditions, is another short-term adaptation measure. Favoring the application of organic and microbiological fertilizers, which will improve the process of matter circulation and energy flow in the agroecosystem and thus improve the potential fertility of the soil.

Most medium-term adaptation measures are related to improving soil fertility and improving its activity, while long-term, most expensive but also the most effective measures include the selection of new cultivars and hybrids resistant to drought and are able to more efficiently use available moisture, setting up buffer zones, changes in the use of agricultural land, reconstruction and improvement of irrigation systems, installation of anti-hail nets and frost protection systems.

Maize as our most important field crop suffers great consequences, which can be concluded based on the current situation (hot summer 2021). Figure 8 shows the risks in maize production in the present and predictions of trends in the future. Regarding the optimal sowing date for maize (Figure 8-a), the South Banat, Belgrade and Central Banat regions are currently the most endangered, with a tendency of invariability in the future. In other regions, the risk is low or moderate with a tendency to increase. One of the measures of adaptation is earlier sowing dates and cultivation of maize hybrids of shorter vegetation with the introduction and forcing of crop rotation with a larger number of fields. The effectiveness of these measures is strong. In addition to crop rotation, improve the existing cultivation system in order to efficiently store winter moisture reserves (autumn tillage, increase land cover by growing cover crops, additional crops and intercrops), as well as shallow plowing of stubble during the summer after harvesting winter crops, because they are the most common forecrops to maize. These are the cheapest measures, the profitability is very high because it has a positive impact on other risks in the production of maize, very applicable, both at the local and national level. These measures have pronounced multifunctionality because they reduce the negative impact of high temperatures and lack of precipitation in the critical period of maize crops, reduce soil erosion and reduce the cost of weed control by applying herbicides, and, of course, have a positive impact on the environment[10]. The largest investments within these measures would be related to education, connectivity and the availability of information to agricultural producers. These measures should be provided for by the "*Strategy*" at the state level, and the implementation and monitoring should be entrusted to advisory services at the local level.

The biggest, high and moderate, risks now, with a tendency to increase in the future, are in relation to high air temperatures and the lack of precipitation in the critical period for maize (Figure 8-d). In addition to the above measures, which also apply here, it is recommended to grow more resistant hybrids of maize with increased abscisic acid content (ABA) that tolerate drought more easily, then work on the selection and creation of hybrids with increased resilience (leaf arrangement, tree height, etc.). Work on creating hybrids that have an accelerated growth at the beginning of the vegetation period in order to close the vegetation area as soon as possible, shade

10 Dragicevic, V., Dolijanović, Ž., Janosevic, B., Brankov, M., Stoiljkovic, M., Dodevska, M.S., Simić, M. (2021): Enhanced Nutritional Quality of Sweet Maize Kernel in Response to Cover Crops and Bio-Fertilizer. Agronomy 2021, 11, 981. https:// doi.org/10.3390/agronomy11050981

the soil and reduce evaporation or free release of water, and also the earlier past critical period for moisture which is from mid-June to mid-July in our conditions. Soil under broad-leaved crops has been unprotected for a long time. By applying inter-row cultivation, with cultivators intended only for such purposes, the soil is cut and scattered between the rows. In this manner, the following goals are achieved: the existing crust is destroyed and the occurrence of a new one is prevented; by cutting the capillaries, a loose layer is created on the surface of the soil, which at the same time prevents excessive release of existing moisture in the soil and increases the ability of the soil to receive new amounts of moisture from precipitation; bulk density decreases with a simultaneous increase in porosity and air capacity, which increases aeration and improves the thermal regime of the soil; weeds from the inter-row space are destroyed, which can be strong competitors to the cultivated crop for moisture. Mulching reduces evaporation in such a way that a smaller area is exposed to the sun and wind. Sun rays reflect more from the brighter surface (mulch is lighter than the ground), which affects the temperature reduction. Chopped materials or smaller substances used for mulch absorb water better and prevent it from swelling or evaporating. The surface under the mulch is more porous without the crust and can absorb more moisture. For these reasons, the soil is more supplied with moisture. Growing a large number of hybrids of different vegetation lengths on one farm is certainly recommended, because in case of an extreme event, different hybrids will be in different phenological phases and will react differently to stressful conditions, and will compensate each other for yield losses, which will enable a safer production on the farm. Within the strategy of sustainable development of agriculture, special attention is paid to the issue of fertilization. Apply fertilizers in accordance with the actual state of nutrients in the soil and the needs of plants, and within the integrated measures, all applied measures should strive to supply the soil with nutrients, as well as by improving the properties that will facilitate the availability of these nutrients to the crop. One of the possibilities of keeping the existing areas under maize is the expansion of the cultivation area (moving towards hilly areas with the improvement of cultivation technology and increasing the number of crop rotation fields. These adaptation measures are also valid for the risk of biological sums of air temperatures in the vegetation period of maize, and in addition to being cost-effective, efficient, applicable, multifunctional, a somewhat greater urgency can be emphasized here because in recent years producers have suffered certain consequences from this risk. Slightly larger funds are needed for the work on breeding and selection, and behind this work, based on the strategy, there should be a state with all the necessary capacities.

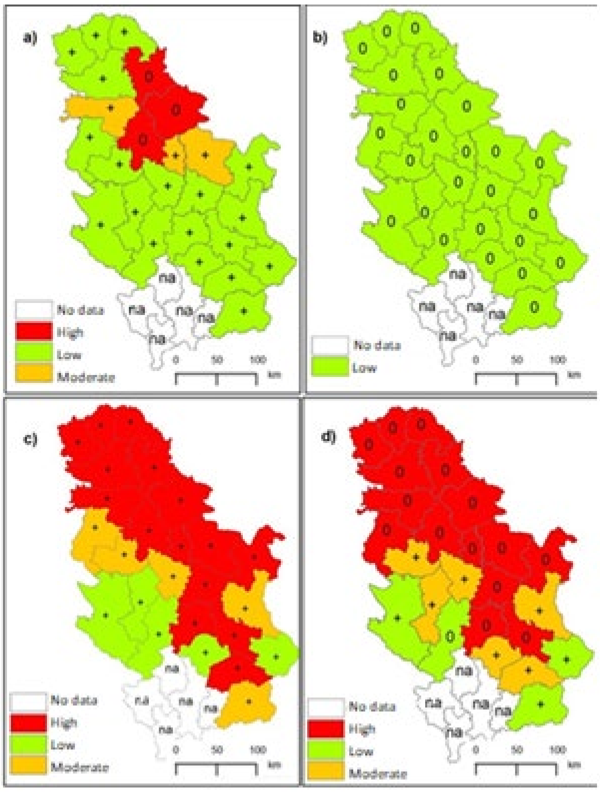

Figure 8. Risk for the optimal sowing time of maize (a), low air temperatures in the initial stages of maize growth (b), high air temperatures and lack of precipitation in the critical period (c) and biological sum of air temperatures in the maize vegetation period (d) and current trends in the future (''+'' - increases, ''-''- decreases, ''0'' - remains stable)

In addition to all the above, for this risk still the most effective, most cost-effective (in the long run) and in some regions of Vojvodina the most urgent measure of adaptation is -irrigation. Irrigation essentially changes all the conditions in one system of plant production, so that in itself it represents a special measure with a more far-reaching impact. There are numerous specific agro-technical measures in the system of plant production with irrigation, and the existing ones require certain adjustments to conditions that are significantly different from those in the natural regime of wetting. This is the most expensive investment of a national character with numerous shortcomings (water, financial resources), and the will to do something about it. The introduction of irrigation systems should be gradual and follow not only the risks in individual regions, but also the areas and intensity of production in those regions.

Winter wheat is accompanied by lower risks in production in the present and with a tendency of invariability in the future (Figures 9 and 10). Moderate risks in relation to the optimal sowing date and lack of precipitation in the initial stages of wheat growth were observed in Braničevo, Zaječar, Raška and Moravica regions and from more important regions there is a moderate risk of lack of precipitation in the initial stages of growth and development in the South Banat region (Figure 9 - a and b). Adaptation measures would be specially analyzed and introduced at the local level and would refer to the timely sowing of more resistant varieties with respect to the basic principles of crop rotation. Considering that maize and winter wheat are the most represented in the sowing structure of the Republic of Serbia, the dominance of two-field crop rotation is inevitable. The introduction of adaptation measures with maize, such as sowing and cultivation of earlier maize hybrids, would contribute to the improvement of conditions for earlier sowing and timely soil preparation for the winter wheat. Care should be taken here, i.e. this applies to areas with lower altitudes, because at higher altitudes, earlier sowing would increase the risk of early autumn frosts. Increasing the frequency of crops in the crop rotation, by introducing other crops such as soybeans, would improve the efficiency of the use of water and nutrients from the soil. Sowing of more resistant varieties with a larger number of plants per unit area is also recommended in the main production regions and on higher quality soil types. In contrast, on poorer soils, in the predicted conditions of the increased trend of the number of dry days for the April-August period, the sowing density should be reduced, especially in years with a low amount of winter precipitation (from September-March). All these measures are effective, cheap, with great cost-effectiveness, very applicable, both at the local and state level. These measures reduce soil erosion and reduce the cost of weed control by applying herbicides, especially to subsequent crops (dense crop effect) and thus reduce the negative impact on the environment[11]. The largest investments within these measures would be related to education, connectivity and the availability of information to agricultural producers.

The risk of the lack of precipitation in the critical period for wheat is currently highest in North Banat, Central Banat, North Bačka and West Bačka, with a tendency to remain stable, and in other regions it is low but with a tendency to increase in the future (Figure 10-a), while high air temperatures in the generative stages of wheat development are mostly a threat in the future (Figure 10-b). A measure that would reduce the impact of water shortage in the critical period for the winter wheat, in addition to growing more resistant varieties, is to improve crop rotation or favour other forecrops (except maize as a large consumer of water) to winter wheat such as soybeans.

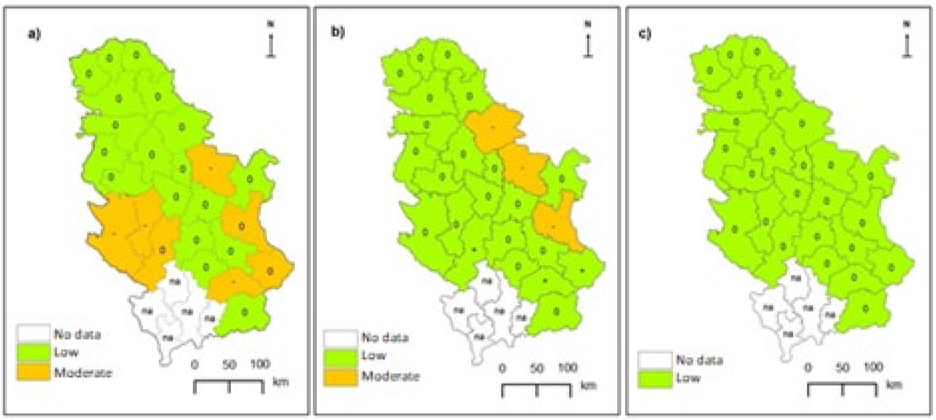

Figure 9. The risk for the optimal sowing period of wheat (a), the lack of precipitation from germination to sprouting (b) and the occurrence of frostbite (c) in the present and the tendency in the future "+"- increases,"-"- - decreases, "0" - remains stable)

11 Djekic, I., Kovačević, D., Dolijanović, Ž. (2020): Impact of Climate Change on Crop Production in Serbia. In: Leal Filho W., Luetz J., Ayal D. (eds) Handbook of Climate Change Management. Springer, Cham. https://doi.org/10.1007/978-3-030-22759-3_36-1

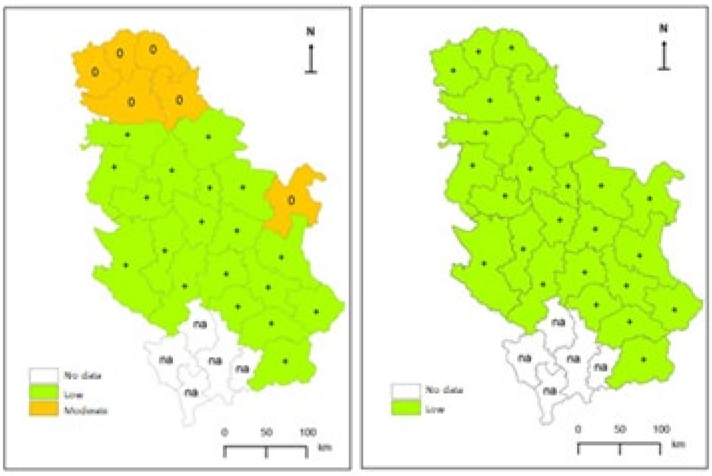

Figure 10. The risk of the lack of precipitation in the critical period for the winter wheat (a) and high air temperatures in the stage of the generative development of wheat (b) in the present and tendencies in the future ("+" increases, "-" decreases, "0'' - remains stable)

Soybeans, currently and in the future, will be exposed to high risks in relation to the optimal sowing period, especially in the South Banat, Belgrade, North Banat and South Bačka region (Figure 11-a). Regarding low air temperatures in the initial stages of soybean crop growth, we notice that the risks are low and there is no threat (Figure 11-b). However, limiting factors in the production of this crop are related to high air temperatures and the lack of precipitation in the critical period for soybeans, and high risks are present in the Central Banat, North Banat, North Bačka, South Bačka, Srem and Mačva regions (Figure 11-c).

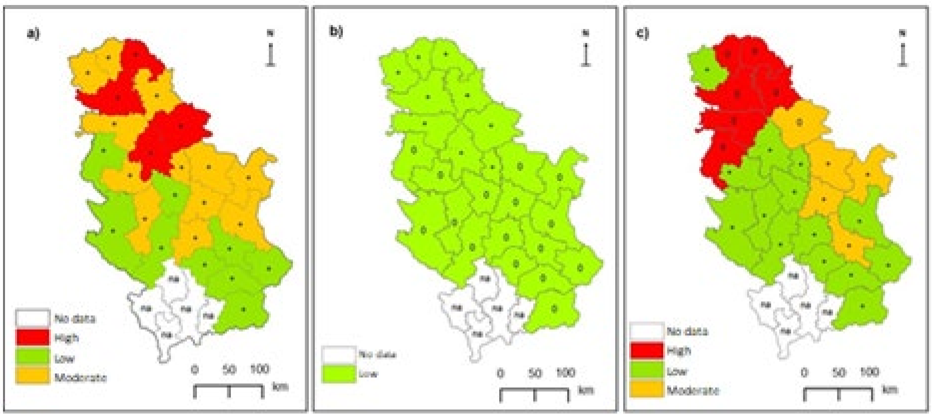

Figure 11. The risk of optimal soybean sowing period (a), low air temperatures in the early stages of soybean crops (b) and high air temperatures and the lack of precipitation in the critical period for soybeans (c) in the present and future trends (''+'' - increases, "-" decreases, ''0'' - remains stable)

Changing the sowing date, i.e. earlier sowing, with the introduction of more resistant varieties of shorter vegetation period (O and I ripening groups) is the most important measure of adaptation, both for the optimal sowing date and especially for the critical phase in which plants would enter earlier and "avoid" high temperatures accompanied by the lack of precipitation. Irrigation as a measure is especially acceptable and necessary during the critical stages of soybean crops and depends on the introduction of crop rotation, so that the irrigation system is in function for the next and forecrops in the subject field. Autumn tillage in order to effectively preserve winter moisture reserves, growing cover crops to increase biodiversity and strengthen crop rotation, as well as combining this crop with other crops primarily from the grass family are "alternative measures", which are especially acceptable on mixed farms where, in addition to arable farming, animal husbandry is also represented. Increasing the area under this species would lead to an improvement in the content of organic matter in the soil, which is inevitable in conditions of poor manure application. Conservation tillage systems, leaving the largest amount of crop residues from the previous crop, would also improve the most important soil characteristics affecting water retention and uptake by soybean crops. Irrigation, as most expensive, most effective, most cost-effective with a pronounced urgency in certain regions, would be the most adequate measure through the quantity and quality of yields. It should be introduced on the basis of a long-term strategy of the state, and the implementation and monitoring should be entrusted to local agricultural services with a strong connection and education of agricultural producers. Other proposed measures are also effective, cost-effective, easily applicable with pronounced regional differences and in any case are part of the strategy of sustainable development of both the primary and other forms of agricultural production. The introduction of these measures should also be entrusted to state institutions (universities, scientific institutes) and implementation and monitoring would be under the supervision of local governments.

Sunflower has a moderate risk in terms of optimal sowing date in the South Banat and Belgrade region (Figure 12-a), in West Bačka, North Banat and Bor in terms of the lack of precipitation during intensive growth and flowering (Figure 12-b) and in all regions of Vojvodina and central Serbia and Jablanica in terms of high air temperatures and the lack of precipitation from flowering to ripening (Figure 12-c). The tendency of all risks for the future is an increase for the most part or unchanged in certain regions (Figure 5).

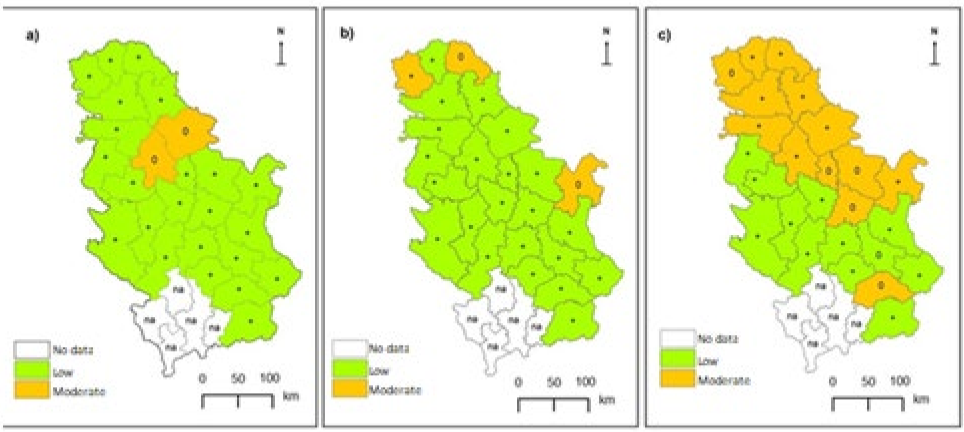

Figure 12. Risk for the optimal sowing date of sunflower (a), lack of precipitation in the phase of vegetative growth and flowering (b) and high air temperature and the lack of precipitation from flowering to ripening (c) in the present and future trends "+" - increases, "-"- decreases, "0" - remains stable)

Of the adaptation measures, crop rotation should be mentioned, the usual forecrop for sunflower is wheat and maize. It is necessary to avoid forecrops such as soybeans, oilseed rape, legumes, because this reduces the efficiency of soil moisture use, but also due to some common diseases.

Since sunflower is more drought-resistant than maize and soybeans, earlier sowing is valid for later hybrids. It is important to cultivate the soil (plowing) in the fall with the greatest possible introduction of crop residues into the soil in order to preserve winter moisture reserves and improve soil properties and organic matter content[12]. Proper crop rotation, properly selected tillage system with adequate selection of sunflower hybrids, based on the specificities of each locality and the purpose of production (oil or confectionary sunflower) are important measures to adapt and mitigate the consequences of adverse climatic factors. These measures have the character of cheaper, effective, applicable, cost-effective and certainly multifunctional because they reduce the cost of investment in the field of crop protection from diseases, pests and weeds, and all this mitigates the negative impact on the environment. Monitoring of positive impact indicators (yield and chemical composition of sunflower seeds) should be entrusted to local advisory services and sublimated data from the local level should be transferred to the national level in the form of a national register, as well as for other field crops. However, much more expensive, and more efficient and cost-effective (in the long run and for more crops) is the irrigation measure that must be introduced at the state level in accordance with a predetermined crop rotation, so that all crops in the crop rotation scheme of each farm benefit from this measure.

Sugar beet is a broad-row crop of earlier sowing in the spring, so the risks for the optimal sowing date are slightly higher than for other spring crops (Figure 13-a). It is especially important to mention the fact that there are high risks of low air temperatures in the period after sowing in the Central Banat, South Banat, South Bačka, Belgrade, Danube, Braničevo and Pomoravlje regions (Figure 13-b). Regarding the lack of precipitation in the critical period for sugar beet, the risk is high in most of the Republic of Serbia, except for the regions where this crop is less grown (Figure 13-c).

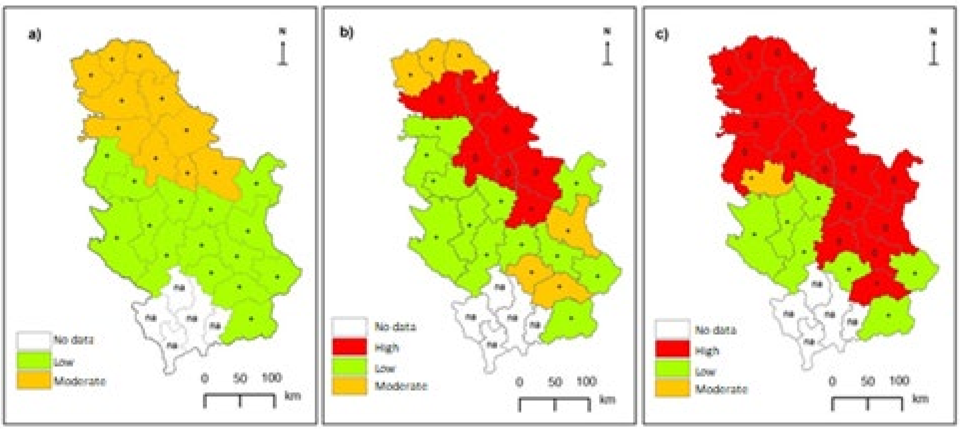

Figure 13. Risk for the optimal sowing date of sugar beet (a), low air temperature in the period after sowing (b) and the lack of precipitation in the critical period (c) in the present and tendency 1in the future (''+'' - increases, ''-''- decreases,''0''- remains stable)

Given the earlier sowing of this species, shifting the sowing dates is uncertain and strives for more acceptable solutions: growing more resistant varieties, optimizing crop density, rational tillage technology with plowing of crop residues, respecting crop rotation rules, adequate fertil-

12 Seremesic, S., Jovović, Z., Jug, D., Djikic, M., Dolijanović, Ž., Bavec, F., Jordanovska, S., Bavec, M., Đurđević, B., Jug, I. (2021): Agroecology in the West Balkans: pathway of development and future perspectives, Agroecology and Sustainable Food Systems, DOI: 10.1080/21683565.2021.1913464

ization based on potential soil fertility and plant needs. All procedures leading to a more efficient absorption and storage of moisture within the integrated control measures (crop rotation, cultivation, fertilization with organic fertilizers, cultivation of cover and intercrops) are acceptable, effective, cost-effective and applicable. Unlike other spring crops, the cost-effectiveness of these cheaper measures is lower in sugar beet, which means that irrigation in this field species is a significantly higher priority adaptation measure, especially in the future when rainfall is expected to decrease during the summer. If the national interest is the cultivation of sugar beet with high digestion and processing into sugar, irrigation is an extremely important measure and the alternative is the import of sugar from sugar cane, which will be increasingly expensive and unavailable in the future.

The main obstacles in the application of appropriate adaptation measures in arable farming at present are:

Very slow increase of irrigated areas, with numerous reasons: economic instability (instability of product prices, high bank interest rates, lack of market, lack of will of producers); poor infrastructure (inadequate road network and inability to connect to the electricity system); insufficient availability of water sources in areas with higher altitude, remote watercourses/canals in lowland areas, the problem of water supply, low groundwater yield; poor arrangement of drainage canals because drainage of the terrain is a mandatory prerequisite for successful irrigation.

Further, the disadvantages are:

- Underdevelopment of animal husbandry and processing capacities, which rely on arable farming;
- Inconsistency of the state policy in conducting agricultural policies;
- Lack of development of professional/advisory assistance;
- Insufficient development of the forecast service for monitoring new invasive pathogens of plant diseases, weeds and pests that develop in the conditions of climate change;
- Insufficient supply of raw materials (high-yielding varieties and hybrids resistant to drought, mineral, microbiological and organic fertilizers, especially manure, plant protection products);
- Age structure of the agricultural population, etc.

Proposal/Recommendations for amending and/or drafting new legal, planning and strategic documents in accordance with the findings from previous activities

Without the adoption of strategic documents within a strong agricultural policy and without the allocation of significant funds from the budget, the Republic of Serbia will not achieve significant progress in adapting to climate change. In addition, a document on the long-term development of agriculture and strategic species, at the state and local levels, is necessary, not only written but also systematically implemented and gradually implemented. Recovery of certain regions or at least stopping the process of depopulation in them is possible only with significant investments in those regions in terms of infrastructure (roads, electricity, internet traffic, etc.). In these areas, agriculture should be a consequence of the development of other activities and not a cause of the household decline.

The sequence of activities and steps could largely pave the way for a successful fight against climate change. First, it is necessary to form a national body for the coordination and planning of adaptation measures in the field of agriculture. This body composed of experts of various profiles relying on the field of agriculture should provide support for the development and increase of sustainability in agriculture. This is possible by replacing certain conventional (classical) systems with newer systems (sustainable, integral, organic, urban and precision) of agriculture.

The essence of integrated agriculture consists of all measures and procedures combining advanced techniques from conventional agriculture and biological measures in the control of diseases and pests, mainly defined by the term "integrated protection (IPM-Integrated Pest Management). Today, integrated protection systems rely heavily on software solutions based on automatic meteorological stations, which monitor air temperature and humidity, cumulative photosynthetically active radiation, precipitation and leaf moisture, as well as humidity, temperature and electrical conductivity in the soil, which contributes to increased production efficiency.

Organic agriculture as a model of sustainable agriculture contributes to: food quality and safety, biodiversity conservation, higher energy efficiency and a more pronounced degree of multifunctionality[13]. The increase of biodiversity is accompanied by the improvement and increase of the frequency of cultivated plants through the interpolation of existing crop rotations, the greater practice of multifield crop rotations, i.e. the increase of soil cover with the vegetation cover and organic remains, both in time and space. Such practice contributes to the conservation of soil moisture, preservation of soil structure, control of weed vegetation, protection against erosion, improvement of potential soil fertility, etc. The introduction of large amounts of organic matter into the soil in addition to maintaining and increasing soil fertility plays a major role in carbon sequestration and reducing global warming and climate change.

Precise agriculture is one of the most brilliant solutions that can significantly improve the productivity and profitability of agricultural production, but also the sustainability of the agricultural system and the entire agroecosystem. It is primarily based on the rational use of inputs, which, in addition to significant savings in materials, human and machine work, also contributes to the lower pressure of agrochemicals on the environment. Energy efficiency of production is one of the most important attributes of precision agriculture in which navigation and GPS positioning systems enable full control of all diagnostic parameters of the machinery, where in addition to optimal trajectory, minimum spans, idling and fuel consumption, maintenance and replacement of spare parts are significantly reduced[14]. In the near future, the analytics of large databases will enable the development of decision support systems for crop rotation optimization, field

13 Raphaela, J.P.A., Calonegoa, J.C., Marcondes, D.M., Rosolema, C.A. (2016): Soil organic matter in crop rotations under no-till. Soil & Tillage Research, Vol. 155, pp. 45–53.

14 Momirović, N., Kovačević, D., Dolijanović, Ž. (2021): Technology of plant production in arable farming and vegetables from the humanistic aspect of the protection of man and nature. Scientific-professional gathering: DjordjeRadic- the founder of modern agriculture in Serbia, 180 years since the birth of the first doctor of agricultural sciences among Serbs. Academic Board for the Village of SANU, Belgrade. Book CXSIV, Department of Chemical and Biological Sciences Book 18. Proceedings, 127-165.

bookkeeping, crop type selection, and assortment for appropriate agro-ecological conditions of the growing region, as well as for the selected agricultural system, and defining an adequate response to global warming phenomena and changed demands of the population for agricultural products of high quality and biological value.

Furthermore, it is necessary to fully consider the problem of irrigation, work on the reconstruction of existing and improvement of systems depending on local characteristics and needs in terms of the strategic importance of the species. Significantly improve the availability of knowledge of agricultural producers by intensifying the engagement of advisory services and local self-governments in the field of agriculture. Work on the establishment of mechanisms for financial support to farmers, especially encourages the system of the association of producers at the local level and by the similarity of production areas.

6. Adaptation measures on meadows and pastures

Effective measures of adaptation to climate change and their impact on meadows and pastures of Serbia, in terms of areas one of the most comprehensive within agriculture, require a comprehensive, both professional and scientific and institutional approach. Measures of adaptation to severe drought stress during the summer months would be best performed by spreading sown grasslands, with varieties resistant to impending risks. This would be followed, in cooperation with measures in animal husbandry, regionalization of exploitation (where lawns for sheep, cattle, goats, etc. would be purposefully established and maintained), earlier grazing or mowing would be applied.

Since grasslands are very dependent on the substrate, which under meadows and pastures in Serbia is mostly shallow and with limited nutrients, the basis for the spread of adapted grasslands would include the soil repair measures. Measures to repair the soil under meadows and pastures at higher altitudes would primarily refer to the repair of the chemical composition, and then to the repair of water and air characteristics. Larger amounts of mineral fertilizers and burnt manure should be applied after the calcification of the soil (introduction of lime). Tillage without plowing (harrowing, shallow plowing, rolling) would help the adoption of fertilizers and lime, and help aerate the soil. Finally, regular mowing of lawns at the end of the growing season would reduce the fruiting of weed species, help autumn tillering of grasses and clover, and affect the overall biological properties of the soil.

Measures that can fit into the context of nature conservation-oriented solutions (Natural measures or Nature-based Solutions)can be used in combination with designed solutions, with the potential for application on Serbian grasslands. This includes **conservation agriculture and nutrient management**, through the provision of permanent vegetation cover throughout the year, e.g. by sowing legumes suitable for plowing (sideration) or enriching the soil with bound nitrogen over the roots. In line with the adaptation measures on grasslands is the principle of the **zero tillage, with the optimization of fertilizer input and crop amount**. As part of the measures that connect grasslands and animal husbandry, there is also a natural measure of the **improved livestock and pasture management**, through optimization of grazing, improved nutrition through more energy-efficient fodder from sown grasslands, with the use of manure on grasslands as organic fertilizer from the soil-plant-animal cycle, and finally improving the species composition of animals which would affect the use of grassland[15].

All the above measures are applicable throughout Serbia, with the former being more applicable at lower altitudes and the latter at higher altitudes. The problem with adaptation measures is the lack of information from meteorological stations, which are not evenly distributed at higher altitudes and do not follow the local climate, which is highly dependent on altitude changes and the orientation of grasslands towards the cardinal points. Also, changes in the method of using agricultural land, conversion or use of meadows and pastures for other purposes (construction, expansion of the road network, afforestation, temporary conversion into arable land ...) are being made in the regions without care. The solution of adaptation measures must be reduced to the local level and to regional services: agricultural professional services, agronomists within local self-government units (municipalities), and to the Ministry of Agriculture.

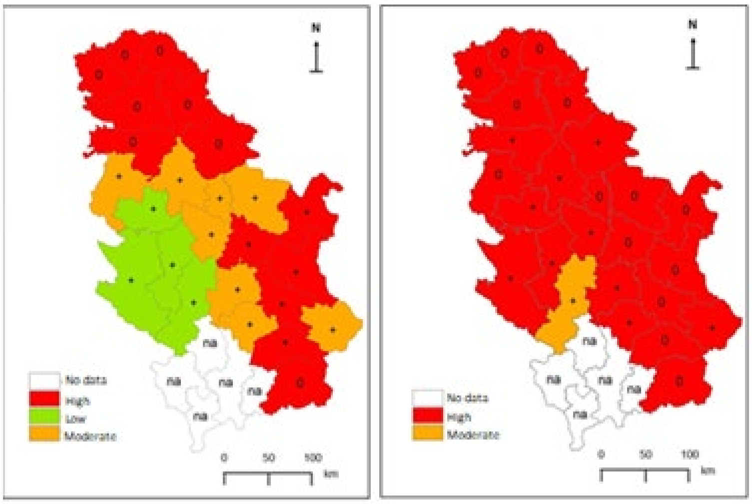

Figure 14. Risk for meadows and pastures to be exposed to drought stress (less than 150 mm and less than 200 mm) during the summer months (June, July and August, cumulatively for three months) (''+'' - increases, ''-''- decreases,''0''- remains stable)

Based on the analysis and forecasts for the future period, two regions are clearly distinguished where there may be high risks of precipitation deficit during the summer (<150 mm), and these are the area of Vojvodina and the area of eastern and southeastern Serbia. Moderate risk occurs in the area of Posavina and the Danube region, as well as in the mountainous areas of southern Serbia. The risk is low for the area from the Valjevo Mountains to Kosovo in the south, as well as from the Podrinje to the Ibar River. There is a tendency of changing and increasing the risk everywhere, except for Vojvodina, where it is high and not progressing.

15 VukovićVimić, A., Petrović, N., Weinreich, A., Pistorius, T. (2021): Nature-based Solutions for climate change and potential for their implementation in Serbia, UNDP, Belgrade, Serbia.

On the other hand, only the area of southwestern Serbia is exposed to a small risk of precipitation deficit <200 mm during the summer months, while the rest of Serbia is at high risk and in a good part of Serbia there is an increasing tendency to reduce precipitation.

Table 5. Criteria for prioritizing drought adaptation during the summer months in meadows and pastures

Criterion	Value
Efficacy	3
Cost effectiveness	3
Applicability	3
Urgency	4
Multifunctionality	4

7. Adaptation measures in animal husbandry

One of the most important adaptive measures is the selection of domestic animals for more efficient production and resistance to heat stress. The funds that would be invested in this measure already exist, because high-quality breeding heads of all types of domestic animals are being subsidized. It is only necessary to redefine breeding programs and switch the focus from production characteristics to characteristics of improved resistance to heat stress and more efficient production. This measure is within the competence of the Main Breeding Organizations which define and control the implementation of breeding programs, as well as basic and regional breeding organizations which implement them.

The Agricultural Advisory Service of Serbia (PSSS) employ at least one livestock engineer, who, in addition to additional training, could hold courses related to new procedures in the preparation of animal feed, as well as the possibility of introducing new plant species that can be used for feeding domestic animals and which better tolerate changed climatic conditions. Also, the manner the meal is conceived, the way of eating and the changes in the production technology can be transferred to the producers using advisors and their contacts with the producers. Advisors can also be involved with additional training in monitoring the microclimatic conditions in facilities for keeping animals, as well as give suggestions on the methods to mitigate the negative effects of adverse microclimatic conditions.

Bibliography

Djekic, I., Kovačević, D., Dolijanović, Ž. (2020): Impact of Climate Change on Crop Production in Serbia. In: Leal Filho W., Luetz J., Ayal D. (eds) Handbook of Climate Change Management. Springer, Cham. https://doi.org/10.1007/978-3-030-22759-3_36-1

Dragicevic, V., Dolijanović, Ž., Janosevic, B., Brankov, M., Stoiljkovic, M., Dodevska, M.S., Simić, M. (2021): Enhanced Nutritional Quality of Sweet Maize Kernel in Response to Cover Crops and Bio-Fertilizer. Agronomy 2021, 11, 981. https://doi.org/10.3390/agronomy11050981

FAO (1985): Water quality for agriculture. R.S. Ayers and D.W. Westcot. Irrigation and Drainage Paper 29 Rev. 1. FAO, Rome. 174p.

Howden, S.M., Jean-François, S., Tubiello, F.N., Chhetri, N., Dunlop, M., Meinke, H. (2007): Adapting agriculture to climate change. Proceedings of the National Academy of Sciences of the United States of America.

http://www.minpolj.gov.rs/download/program-razvoja-vinarstva-i-vinogradarstva-republike-srbije-za-period-2021-2031-godine/

Lazarević, R. (2017): Kako sačuvati i osnažiti resurse u poljoprivredi i na selu. Proceedings "Globalizacija glad u svetu, nove tehnologije i njihov uticaj na proizvodnju hrane", Academy of Engineering Sciences of Serbia, Belgrade, 1-10.

Project: Adaptation of the autochthonous gene pool of fruit trees and vines to the changed climatic conditions with the aim of achieving sustainable production. Ministry of Environmental Protection R. of Serbia, 2019

Raphaela, J.P.A., Calonegoa, J.C., Marcondes, D.M., Rosolema, C.A. (2016): Soil organic matter in crop rotations under no-till. Soil & Tillage Research, Vol. 155, pp. 45–53.

Seremesic, S., Jovović, Z., Jug, D., Djikic, M., Dolijanović, Ž., Bavec, F., Jordanovska, S., Bavec, M., Đurđević, B., Jug, I. (2021): Agroecology in the West Balkans: pathway of development and future perspectives, Agroecology and Sustainable Food Systems, DOI: 10.1080/21683565.2021.1913464

Soil Atlas of Europe. (2005): Luxembourg: European Communities.

Momirović, N., Kovačević, D., Dolijanović, Ž. (2021): Technology of plant production in arable farming and vegetables from the humanistic aspect of the protection of man and nature. Scientific-professional gathering: DjordjeRadic - the founder of modern agriculture in Serbia, 180 years since the birth of the first doctor of agricultural sciences among Serbs. Academic Board for the Village of SANU, Belgrade. Book CXSIV, Department of Chemical and Biological Sciences Book 18. Proceedings, 127-165.

Census of Agriculture, Book 1 (2012): https://pod2.stat.gov.rs/ObjavljenePublikacije/Popis2012/PP-knjiga1.pdf

VukovićVimić, A., Petrović, N., Weinreich, A., Pistorius, T. (2021): Nature-based Solutions for climate change and potential for their implementation in Serbia, UNDP, Belgrade, Serbia.