Impact of climate change on potato production in Montenegro and options to mitigate the adverse effects

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ABSTRACT

Information on Earth's intensive climate changes are coming daily from all over the world and weather is not as it used to be. The weather conditions are becoming more extreme, and the emergence of weather disasters increasingly frequent (floods, drought, high temperatures, windstorms, fires, etc). The impacts of global climate change are felt in almost all spheres of human life. Due to the direct dependence on climatic factors, the agricultural sector is one of the most vulnerable. A number of studies in this area suggest that the impact of climate change in the future will increase, and the negative consequences for agriculture more intensive. These effects will be particularly pronounced in the Balkans, which has been recognized as a region with high sensitivity. Potato is the fourth largest source of food worldwide, and an excellent crop in fight against hunger and poverty. It can be grown in less favourable production conditions and at high altitudes. Potato is ideal crop for areas with a shortage of arable land and an excess input of physical labour, which is common in most of underdeveloped and developing countries. However, in recent years potato production is becoming more sensitive to various types of natural hazards. Increasing climate variability causes large seasonal fluctuations in the amount and quality of yield. Potato favours chilly nights, which are in conditions of global climate change less frequent. Therefore, the potato production is gradually moving from warmer south to colder northern areas, and the higher mountain regions, respectively. Apparently potato will be a less frequent crop. Currently, there are about 7 billion people on earth, and it is anticipated that this number could surpass 9 billion by 2050. In order to meet increasing demands for food, the agriculture production should increase by 60-70% until 2050. However it will not be an easy task. This will force many farmers to adapt a variety of innovative approaches to agro-ecological conditions prevailing in their fields, including, among others, the abandonment of cultivation of certain crops and introduction in the production of new ones.

Key words: Climate change, harmful consequences, potato.

INTRODUCTION

It is obvious that the climate is changing intensely and that the change brings new challenges. To a lesser or greater extent, climate changes are happening in every part of the globe - from the equator to the poles (Gearheard et al., 2010). Although the Balkan is situated in an extremely favourable climate, area weather conditions in this region are becoming more extreme with more frequent occurrence of extremes (heat and cold waves, floods and droughts).
These are the reasons why the Balkans has been recognized as one of the areas that are the fastest warming on Earth. The variability of the climate in this region is so obvious that it almost became a reality. Extreme weather conditions have marked most of the year in the 21st century: the floods in 2004, 2006, 2009, 2010 and 2014, drought in 2000, 2003, 2007, 2011 and 2012, while 2015 was one of the warmest since measurements are performed in this region.

As the climate is rapidly changing, probability of adverse weather conditions could increase significantly in the future. However, currently there is no clear indication of the direction and the dynamics of these changes. Unfortunately, there are predictions that the climate could change much more quickly than was the case in the past. There are many indicators that suggest that the climate is changing rapidly: the number of days with tropical temperature is rising, periods of drought are longer and more frequent, and number of days without rain is increasing, but also the intensity of precipitation. Drought periods during the summer are more frequent and longer, and rainfall during the winter months is intensive and with flood potential (Micev, 2014). In addition, the level and sea surface temperature are increasing (increase of sea levels at the end of this century could exceed 1 m), it is intensified the phenomenon of forest fires, wind storms, etc (Pavicevic, 2012).

The impact of climate change on agriculture is already noticeable, and the consequences of these effects differ from region to region. Almost all relevant studies agree that poor and developing countries, especially those located in tropical and subtropical zone, are mostly influenced by the effects of these changes. South Africa and South Asia are among the most vulnerable regions in the world. In this area in the future are expected very large losses in agricultural production (Lobell et al., 2008). Least harm will suffer developed countries in temperate climates, not only because of the climatic characteristics but also because of significantly greater opportunities for adaptation. On the other hand, in some parts of the world, due to the increase in temperature and carbon dioxide concentration, it is expected growth in agricultural production. Overall, the long-term effects of climate change on agriculture will be very negative, threatening global food security. The agricultural sector in these processes can have a dual role. It can contribute to mitigating the negative impacts of climate change, but it can also be the cause of their formation. Around 14% of total emissions of greenhouse gases come from agriculture. A new approach to agricultural development based on the principles of sustainable development would lead to the reduction of such emissions, and long term reduction of global warming.

Apart from the direct effects of climate change, agricultural production will be threatened by increase of winter and early spring temperatures, by new weed species, diseases and pests. Due to extended periods of drought and high temperatures, wind erosion can be significantly increased (Savic et al., 2002). All this suggests that climate change is a much more complex process than was previously thought. Fear that abrupt climate change, due to lack of time for optimum natural selection and adaptation, could significantly harm agriculture is quite justified. Bearing in mind that agriculture is very sensitive to climate change; this development requires urgent adaptation measures. That is why social efforts must be maximally focused on establishing effective and sustainable systems of adaptation (Jovovic et al., 2015a).

The potato is a plant of temperate climate which, due to strong polymorphism, quite easily adapts to different environmental conditions. As a result, this culture is now grown in almost all conditions, even at high altitudes, where the cultivation of other field crops is not possible. However, in recent years potato production is becoming more sensitive to various types of natural hazards. In addition, climate change and loss of habitat is the greatest threat to the survival of wild species of potatoes. The latest research suggests that 13 wild species and about 52% of natural habitats could be permanently lost by 2050 (Jovovic et al., 2013). With the decrease of genetic variability, a real distribution will decrease and ability to adapt to various changes in the environment, including new diseases, pests and climate change (Hammer and Teklu, 2008).

Numerous studies around the world predict that the impact of climate change in the future will be more visible and will have long term effects on agriculture, and thus on sustainable food supply. These processes will inevitably affect plants, animals and people, but also all other life forms on the planet (Jovovic et al., 2013). According to forecasts of the International Food Policy Research Institute (IFPRI), for the four major food source in the world - wheat, rice, corn and potatoes will be steadily decreased up to 2050, and many farmers in the world will be obliged to produce new crops. The impact of climate change will be felt least in wheat, but it will not be enough to compensate for the losses in other major crops. Ability to adapt to climate change and sustainable production will represent a growing challenge for agriculture. The expected effects of climate change are very complex and far-reaching, and therefore it is quite logical that a number of global initiatives focus precisely on these problems. All these factors give to this phenomenon a whole new dimension.

**Main climate change indicators in Montenegro**

Different climate anomalies are increasingly occurring on the territory of Montenegro. Due to the frequent variations of climate parameters, normal weather conditions have been seriously undermined. Although Montenegro, as a small geographical space, does not affect the global climate change, it nevertheless suffers from the impact.

If we analyze the climatic anomalies, expressed through
differences in values of climatic parameters between climate normal (1961-1990) and the period from 1991 to 2014, we come to the evidence that the climate in Montenegro is rapidly changing. There is an increasing frequency of extreme rainfall and floods, extreme air temperatures, drought, extreme tidal waves and strong waves in the sea and coast. Climate change is increasingly reaching extremes. Cold waves from the north are colder and from warm south, now even hotter (Micev et al., 2012).

Extreme climatic conditions are occurring in almost all parts of Montenegro (Micev, 2010). From the aspect of agricultural production, temperature is one of the most important climatic parameters, and it is in temperature regime that these anomalies are most pronounced. Heat regime has a very significant impact on the dynamics of phenology of potato. Constant growth of air temperature is happening both in winter and in summer. Compared to the climate normal of the average annual air temperature in Podgorica (area of modified Mediterranean climate) in the studied period increased by 0.9°C and it is 16.2°C, and for 1.4°C temperature is higher than the average in the vegetation period (22.8°C). Air temperature especially increases in the hilly and mountainous area. In comparison to the period 1961-1990, the average annual temperature in Bijelo Polje (area of continental climate) increased by 1.3°C and it is 10°C, and in the vegetation season by 1.8°C (16.8°C). Growth of temperature in relation to climate normal was recorded in Zabljak (area of harsh mountain climate). The average annual temperature in this municipality increased by 1.2°C and it is 5.9°C, and in the vegetation season by 1.5°C (13.1°C).

The number of tropical days and duration of warm tropical waves is significantly increasing in Montenegro. For the last 24 years, the average annual number of tropical days (maximum daily temperature reaches and exceeds 30°C) is significantly increased, from 32% in Podgorica (from 66 in the period 1961-1990 to 87 days in the period 1991-2014), to 94% in Niksic (area of moderate continental climate) (from 16 to 31 days). It is interesting to note that 59% of the June, 87% of July and 86% August days in Podgorica have a tropical character, and that 15% of days during June, 40% of days in July and 45% of days during August have high tropical temperatures (maximum temperature reached and exceeds 35°C).

It is evident the increase of the average annual number of summer days (maximum daily temperature during the day reaches and exceeds 25°C). The average number of summer days in Podgorica has increased from 129 to 145 days (over 12%) and in Bijelo Polje from 73 to 86 days (over 18%). In the summer months, even in the high mountain areas, significantly increased the percentage of summer days. Thus in Zabljak (1450 m above sea level) in July 25% of days has summer character, unlike the period 1961-1990, when July had only 9% of summer days. Compared with the normal climate average, annual number of days with frost in Podgorica dropped from 26 to 23 (compared to the normal climate is less than 13%), in Bijelo Polje from 107 to 98 days (for 8%) and Zabljak 167 at 150 days (less 10%).

In terms of amounts of precipitation, there were no significant differences between the observed periods, but there are significant changes in precipitation regime - pronounced rainy and dry periods of the year. In relation to climate normal (1961-1990), rainfall in the vegetation period in Podgorica increased for about 5%, and in Bijelo Polje for about 3%. In the same period in Zabljak was recorded decrease of rainfall in the amount of 7%. Increase in Podgorica and Bijelo Polje is a result of increased rainfall in September (in Podgorica 26% and Bijelo Polje 34%) (Micev, 2002).

Based on comparative analysis of the most important meteorological parameters can be concluded that the number of very cold days in Montenegro is decreasing, the number of very hot days is increasing, but duration of heat waves is increasing as well. The number of days without rain is increasing, but also the intensity of precipitation. Reduction of number of days with strong precipitation and increase of the amount of precipitation on that period indicates to the increase precipitations intensity, as well as the occurrence of extreme unfavourable weather conditions such as flooding (Micev, 2015a; Micev, 2010). All this leads to sudden changes in air temperature, sudden changes in the precipitation regime, as well as changes in the type of precipitation. In some seasons, rapid growth of snowfall occurs, followed by years without snow. All of this fits into the global picture of climate change in Montenegro (Micev et al., 2012; Micev, 2015b).

Climate change and potato production in Montenegro

In 2014, potatoes were grown at 2137.7 hectares (1645.1 ha of arable land and 492.6 ha of yards) in Montenegro with a total annual production of 31,097 tons (http://www.monstat.org). In total production structure on arable land, potatoes have a share of about 25%.

The main area of production of early potatoes in Montenegro is located in the wider area of the Municipality of Podgorica and on coast at the surrounding mountainous terrain up to 600 m a.s.l. Due to the uneven distribution of rainfall during the year; this zone is characterized by emphasized aridity, with long drought periods (Jovovic et al., 2013; 2012). Production of potatoes for storage is concentrated to the central and hilly area. Yields of potato in Montenegro are quite low (about 15 t ha⁻¹), very unstable and very susceptible to weather conditions (Jovovic et al., 2015b). Many factors that affect this situation in potato production: the low level of applied technology, growing potatoes in long-term monoculture, fragmentation of production plots, limited application of mechanization, limited application of irrigation, relatively small scale of use of certified planting material, as well as growing pressure of climate change (high summer temperatures, longer periods
of drought during the growing season, abundant rains that often result in floods etc) (Jovovic et al., 2012).

More frequent extreme climatic conditions represent one of the major problems in last 10-15 years that are facing potato producers in Montenegro. In such circumstances, potato production is becoming more sensitive, which is manifested by large fluctuations in the amount and quality of yield. The greatest damage to the crop of potatoes is inflicted by high temperatures, drought and excessive rainfall. Damages are often manifested through bigger or smaller crop decays, increased cost of replanting, more intense occurrence of pathogens, increased cost of crop protection, increased soil erosion, etc. Moreover it should not be ignored the damage caused to agricultural buildings and stored products.

**Damaged caused by high temperatures**

High temperatures of air and soil have a negative impact on the growth and development of potato. At high temperatures (above 25°C, and especially higher than 30°C) shortens the growing period of potatoes and reduces tuber yield. High soil temperatures stimulate formation and branching of stolons, which directly adversely affects the yield. The physiological processes in plants significantly slow down at the soil temperature higher than 25°C, while at the temperature higher than 29°C formation and bulking of tubers. Long-term effects of high temperatures from 30 to 40°C during the formation of tubers cause degeneration of potatoes, particularly in the early varieties.

As a consequence of global warming, it often happens that in a large part of the day, in the rhizosphere layer, temperatures are above 28°C. In such conditions, even with sufficient amount of soil moisture, yield and quality decrease (reduced percentage share of the market tuber), due to more intense respiration processes than assimilation processes. High soil temperatures lead to secondary growth of tubers and chain tuberisation.

The analysis of climate parameters shows that the number of very hot days and duration of heat waves in Montenegro continuously increases. Depending on the phenological phases in which they occur, high temperatures regularly cause minor or major reduction in potato yield and its quality.

Global climate change with an increase in average air temperature is gradually affecting spreading, spatial distribution and intensity of existing pests, diseases and weeds. Potato producers in Montenegro are increasingly faced with the emergence of new pests. As a consequence of global warming in recent years in this region is registered the massive phenomenon of potato tuber moth (Phtorimaea operculella Zell). Potato tuber moth is a pest of potatoes in the field and in storage with incurred damage right after the Colorado potato beetle. Although it is most common in tropical and subtropical areas, due to warmer summers, this pest is becoming more frequent in this part of Europe. The optimum temperature for the development of potato tuber moth is 27-35°C. Caterpillars drill potato tubers that are rotting and decaying. These tubers are practically unusable for human consumption. In our conditions Moth develops 5-7 generations. It causes greater damage in warmer regions, as it forms a larger number of generations. Although in this part of Europe, moth appeared almost 30 years ago, serious damages were registered in 2012, 2013 and especially in 2015. Damages to potato crops were in the range 25-80% and in some cases 100%. In Montenegro, this harmful organism was first registered at the end of the 80s of the last century, but since then has never been found in the potato crop. Post controls of potato tuber on the presence of two potato moths: P. operculella Zell. and Scrobipalpopsis solaniwora Polovny is mandatory component of the certification of seed potatoes in Montenegro. P. operculella Zell has not been recorded in seed production, but has been found in consumable potatoes originating from import (surrounding countries).

**Damages caused by drought**

The greatest impact of climate change on agriculture will be through water sources. Expected changes in the regime of summer rainfall will result in reduction of amount of water available in agriculture in many parts of Europe, particularly in southern and central parts. In the coming period, it is expected an increased frequency of droughts, especially in the southern parts of Europe, and therefore in Montenegro.

Drought is the most common cause of stress in potato (Onder et al., 2005). Increasingly frequent rainfall deficit during the vegetation period, caused by global warming is one of the biggest risks that threaten potato production (Miyashita et al., 2005), and the incidence of stress caused by drought will obviously increase in future (Chaves et al., 2002). Lack of water is the most important limiting factor in potato production (Reddy et al., 2004). During the drought, potato tubers formed are smaller, of poor quality and susceptible to secondary growth. The greatest water needs of early varieties of potatoes are in June and July, mid early and mid late varieties in July, August and late varieties in July, August and September. If in the period July - August appear long droughts, potato yield is significantly reduced, whereby secondary tubers are formed.

The decrease in yield can be affected even by short periods of drought, especially if they occur in the early stages of the formation of tubers. At this stage, drought favours the emergence and development of common scab (Streptomyces scabies Lambert & Loria), while in the later stages favours occurrence and attack of potato tuber moth, which arrives to the tubers through the cracks in the soil. In addition to the drought, the extent of common potato scab is significantly affected by the increased acidity of the soil in...
the major production regions of Montenegro, especially in highland areas.

Drought hampers the performance of agro-technical measures, and dry land increases the number of tubers damaged during harvest. At the end of the growing season, when the foliage dries, the land becomes more exposed to the sun, and drought can cause physiological damage to tubers (Muminovic et al., 2014). Under conditions of pronounced lack of water, such as in Montenegro was the case in 2000, 2003, 2007, 2011, 2012 and 2015, there is a significant decrease in yield of potatoes. Depending on the intensity of drought this reduction is from 30 to 70% (Jovovic et al., 2015a).

**Damage caused by excessive rainfall**

Increased frequency of intense rainfall can be felt everywhere in Europe. Potato production in Montenegro in recent years suffered significant damage caused by excessive rainfall, which in some years have the character of extreme precipitation - flooding. Potato plants are sensitive to the flooded soils and due to lack of oxygen; potato roots potatoes are quickly irreversibly damaged.

Excessive precipitation significantly hampers the production of potatoes in Montenegro, and sometimes completely destroys it. The problem of excessive precipitation is especially pronounced in the production of early potatoes, where heavy rains during planting cause significant yield losses and reduce the quality of tubers. In addition, significantly increases the production costs. Harmful effects of excessive rainfall are mainly reflected through late planting, crop decay and additional costs of replanting. In rainy years, especially in those with a large amount of rainfall at the beginning of the vegetation season, it is intensified the incidence of different pathogens Pectobacterium carotovorum subsp. carotovorum van Hall, Pectobacterium atrosepticum van Hall and Dickeya chrysanthemi Burkholder. Massive disease outbreaks present additional challenge in the production of potatoes, as in addition to a decline of yields, due to the increased use of chemicals, and significantly increase production costs (Jovovic et al., 2015a). In cold and wet growing seasons, as it was in Montenegro in 2012 (in the period from February to April sum of precipitations was 552.1 mm), these pathogenic bacteria elicit a lot of damage. The disease usually occurs in the period between planting and emergence, and susceptible plants don’t form tubers (Brogic et al., 2005). A significantly higher level of infection was observed in crops with earlier planting dates and on heavier soils (Jovovic et al., 2015b).

The consequences of excessive humidity are felt in the production of potatoes for storage. The most harmful effects are reflected in the reduction of yield caused by late planting or massive emergence of fungal and bacterial diseases (Jovovic, 2011). High humidity during the vegetation period, accompanied by high temperatures, creates a favourable environment for the emergence and development of fungal diseases, particularly potato blight (Phytophthora infestans (Mont.) De Bary). Late blight can halve or completely destroy the production if appropriate protective measures are not taken (Bugarcic, 2000). In such circumstances, it is necessary to intensify the protection of potato - start with early protection, increase the number of treatment and shorten the period between the two treatments (Milosevic, 2009).

Epidemics of late blight in Montenegro took place in 1999, 2001, 2004, 2010 and 2014. Particularly severe attack of late blight was registered in 2014, when the disease completely destroyed or significantly damaged more than 40% potato crops. In addition to climate change, such huge damages are often caused by the wrong strategies to control late blight (Muminovic et al., 2014). In last twenty years, this pathogen has dramatically evolved which led to the emergence of some very aggressive strains from the centre of origin - Mexico and are slowly spreading in Europe. The development of new types of late blight is much faster, and pathogen is adapts to lower and higher temperatures (Mulder and Turkensteen, 2005). The expansion of sex type A2 from Mexico created the conditions for full multiplication of pathogens and thus new risks in potato production (Milosevic, 2009).

It is believed that climate change will affect the appearance of new diseases. Given that in Montenegro is registered phytoplasma Stolbur on grapevines (Radonjic et al., 2009), the vector - cicada Hyalestes obsoletus Signoret and weed plants that are natural hosts of the phytoplasma (Convolvulus arvensis L., etc.), stressed the need of determining the presence of Stolbur in potatoes. The above facts clearly show that there are all the conditions in Montenegro for the emergence of Stolbur on potatoes. For these reasons, in 2015 were collected numerous samples of potato plants with symptoms of Stolbur for molecular analysis.

Unfortunately, the damage from extreme rainfall (floods) occurs even during the winter months, during storage of potatoes. Thus in Niksic, in 2010, due to the flooding, it destroyed the entire stock of stored seed potatoes (about 500 tons). That year, only during November and December level of rainfall was 1121.7 mm, the storage was under water more than 20 days, and due to large water pressure, damages on building and stored plant material were huge. As the potatoes were stored in bags, in the moment of peak of flood (height of the water column was 1.8 m) all potatoes was under water. The entire amount of stored material has been destroyed, because the potatoes and was further threatened by low temperatures (night temperatures were -10°C) (Jovovic et al., 2015a). Damages to stored seed, plant and equipment, including the cost of municipal services for transport of potatoes to the city landfill, were estimated to over 350,000 €.

Heavy rains, except for crops, can be harmful to soil
Table 1. Metrological data in vegetation period for municipality Kolasin (area of continental climate).

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Average</th>
<th>Average monthly air temperatures (°C)</th>
<th>Monthly precipitation sum (mm)</th>
<th>Number of tropical days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>June</td>
<td>July</td>
<td>August</td>
<td>September</td>
</tr>
<tr>
<td>2014</td>
<td>11.3</td>
<td>15.3</td>
<td>17.3</td>
<td>17.5</td>
<td>12.8</td>
</tr>
<tr>
<td>2015</td>
<td>13.8</td>
<td>15.9</td>
<td>20.3</td>
<td>20.1</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Table 2. Potato yield (t.h⁻¹).

<table>
<thead>
<tr>
<th>Year</th>
<th>Variety</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Riviera</td>
<td>Arrow</td>
</tr>
<tr>
<td>2014</td>
<td>21.2</td>
<td>20.5</td>
</tr>
<tr>
<td>2015</td>
<td>17.3</td>
<td>21.4</td>
</tr>
</tbody>
</table>

structure. Hits of raindrops destroy the soil structure and separated particles are easily moved with water down the slope. The finest soil structure is lost (humus, clay, dust, etc) and thereby reducing fertility. Since water removes finest particles of soil, it modifies the structure of soil making it more porous, with reduced water retention capacity. Mostly susceptible to erosion is puffy, surface layer of soil, although sometimes deeper layers can be affected. The effects of water erosion can be large, due to removal of arable layer that can lead to permanent loss of soil. Once eroded soil represents soil lost forever. If water erosion occurs in the vegetation period, in addition to damage of soil, leads to damage of potato crops, thus making difficult or completely impossible production.

Based on the foregoing, it can be reliably concluded that in whatever form it appears, climatic extremes inflict significant damage to the crop of potatoes. Confirmation of this statement is found in the results given in Tables 1 and 2. Although in Kolasin in 2014 (area of continental climate) fell almost twice as much rain, potato yields were lower than in 2015 (21.5 and 22.2 t.h⁻¹). Reduction in yield in 2014 is a consequence of the large amount of rainfall during the vegetation period, which often led to over wetting of land, and thus suffocation of potato plants. The reason for the decrease in yields in 2015 were extremely high temperatures and drought (average temperature in the vegetation was 2.4°C higher than in 2014). Although Kolašin has continental climate in three summer months of 2015 (July, August and September) were registered 38 tropical days, 35 more than in 2014 (Micev, 2015b). In such conditions the crop of potato, apart from high temperatures, significantly suffered from drought (land and air).

Adaptation to climatic changes

Fighting climate change is one of the greatest challenges that humanity has ever faced. Therefore, the number of initiatives aimed at alleviating the consequences of extreme climate events is growing. In addition to activities to mitigate climate change in the future, more attention will be focused on the development of effective systems of adaptation, because humanity must adapt to the changes that will happen in the next 50 years. In anticipation of climate change, it is necessary to more intensively invest in appropriate agricultural innovations. This will, inter alia, represent work on creating new varieties tolerant to drought, high temperatures, diseases and other stressful situations.

Water shortages, floods, extreme weather events, as well as shifting of growing seasons will have a growing impact on agricultural production. Therefore, farmers will have to intensively adapt to the new climatic conditions. As agriculture is directly dependent on natural ecosystems and processes in it, it is through that preservation of natural resources can be significantly mitigate adverse impacts of climate change. Models of large-scale agricultural
production are not the right answer to the challenges of changing climate and increased demand for food. For these reasons, the small-scale food production, due to greater concerns about the environment, in the future will become more and more important. Therefore for effective adaptation we will need new knowledge and scientific and technological solutions adapted to local conditions. Finding solutions to rationalize consumption and increase efficiency of energy use in agriculture will certainly be one of the important tasks of adaptation. Given that in the future in many areas on the planet temperature will increase and significant changes in precipitation regime will occur, it is obvious that irrigation will be one of the key mechanisms of adaptation.

Soil erosion is another threat to agriculture, which may be effected by climate change. Huge amounts of water each year carry thousands of tons of the finest soil particles and a large amount of organic matter and nutrients from the land on which potato is produced. The expected increase in extreme rainfalls will certainly affect the intensity of water erosion. This is why agricultural land should be kept as possible under the vegetation, preferably during the winter months, regularly fertilized with organic manure and avoiding unnecessarily deep and excessive tillage.

Potato production in Montenegro, due to poor investing, expresses an increased sensitivity to climate variability. More frequent drought will lead to increasing oscillation of yield and the quality of products obtained. Potato is very sensitive to extremes, and for stable production irrigation is indispensable. The future of potato production in Montenegro is directly dependent on water resources. Irrigated area must be significantly increased, but also it should be provided for greater availability and efficiency of water use. The effect of irrigation on the yield of different varieties of potatoes is shown in Table 3. Depending on the variety, increase of the yield of potatoes in irrigation conditions ranged from 83-106%.

In addition to the direct effects of climate change that is manifested through changes of meteorological parameters, agricultural production will have more pressure due to the various types of pests and diseases whose incidence could be significantly increased due to climate change. Adaptation to the conditions that are expected to happen in the future will force many farmers to adapt their own production to the new circumstances. This will sometimes involve the abandonment of cultivation of certain crops and the introduction in the production of some new ones. The new climate conditions will result in favourable conditions for the development of other cultures.

Since the potato grows best in colder regions, due to the increase in temperature, and other climatic disturbances, it can be expected that the volume of its production will suffer serious decline. Based on current trends in potato production, by 2050 a decrease of about 9% (www.ifpri.org) is expected. Some authors believe that potatoes, even at high altitudes where they are currently grown, will be replaced with some other cultures.

Conclusion

The impact of global climate change can be felt in almost all spheres of human life, and due to the direct dependence on climatic factors the agricultural sector is one of the most vulnerable. According to relevant climate projections, it is expected that the impact of climate change in the future will be much higher, and the negative consequences for agriculture more intensive.

Increasing climate variability causes large seasonal fluctuations in the amount and quality of potato yield, which is why this production will increasingly move from the warmer south to the colder northern areas in future, i.e. higher mountain regions.

In addition to the activities aimed to mitigate climate change in the coming period, more attention should be focused on the development and establishment of effective systems of adaptation. In order to oppose more efficiently to the upcoming changes, producer need much stronger state support because they alone have lack of capacity. Meaningful public policy will enable farmers to improve their production systems and to adjust the structure of their farms.

Climate change is a great opportunity for a new approach to the development of agriculture, which will be based on the principles of sustainable development. At the same time, global food security should not be compromised.

REFERENCES


Table 3. Potato yields in Kolasin in 2015.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variety</th>
<th>Arrow</th>
<th>Madeleine</th>
<th>Arizona</th>
<th>Agria</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>Riviera</td>
<td>21.2</td>
<td>20.5</td>
<td>19.8</td>
<td>22.8</td>
<td>23.1</td>
</tr>
<tr>
<td>No irrigation</td>
<td>Riviera</td>
<td>40.4</td>
<td>37.6</td>
<td>40.0</td>
<td>42.7</td>
<td>47.7</td>
</tr>
</tbody>
</table>


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