REPORT ON GENDER-SENSITIVE CLIMATE RISK ASSESSMENTS FOCUSSING ON FILLING THE INFORMATION GAPS AND PRIORITY ACTIONS THAT ADDRESS CLIMATE-DRIVEN VULNERABILITIES AND GENDER-DISAGGREGATED IMPACTS OF THE SECTOR AGRICULTURE

Final draft December 2022

CAOS sustentabilidade

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Acronyms

AST	Adaptation Support Tool
BUR	Biennial Update Report
CC	Climate Change
EC	European Commission
EU	European Union
EEA	European Environment Agency
ETIS	European Tourism Indicator System for Sustainable Destinations
Eurostat	Statistical Office of the European Union
FAOStat	Food and Agriculture Organization of the United Nations Statistical Databases
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
NAP	National Adaptation Plan
NCCC	National Communication on Climate Change
NC	National Communication
SBUR	Second Biennial Update Report
SNC	Second National Communication
THI	Thermal Humidity Index
TNC	Third National Communication
TWG	Technical Working Group
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Scope and objective of this document

The scope of this document is to identify existing and future climate change risks, vulnerabilities and impacts for the Montenegrin agriculture sector. The results will form part of Montenegrin climate change response strategies and support the implementation of the country's wider National Adaptation Plan (NAP). Prior to the development of this report, an analysis of the policy framework has been undertaken in order to identify opportunities for mainstreaming climate change into agriculture related policies and planning processes.

Framework and approach

The methods for climate vulnerability assessment of agriculture sector will be analysed using following methodological approach:

1. Analysis and establishment of the base case (period 1971-2000 as in the climate scenarios of Montenegro, or if downscaling data are the only option the period 1991-2020 can be alternatively taken as a base case)
2. Analysis of the climate change case for all indicators presented in the base case. Climate change case will be centred to year 2025 and 2055 therefore, periods from the year 2011 to 2041 and from 2041 to 2070 respectively were elaborated.
3. Assessment of the exposure and sensitivity based on the changes of the biophysical indicators analysed
4. Analysis of the impact using the Aqua Crop model as difference between yields in base period and in climate change period for two comparison cases baseline with period 2011-2040 and baseline and the period 2041-2070. The crops analysed are maize as representative of the crops with c4 photosynthesis pathway that are characterized by high tolerance to the increased temperatures, winter wheat as representative of the crops with C3 photosynthesis pathway where most of the crops grown in Montenegro belong, and can be used as an indication for the response of all cereal crops in Montenegro, despite maize/some forages in Poaceae family,
5. Expert judgment on the vulnerability based on the analyses of the impacts and expert judgment on the adaptive capacities in the country. The adaptive capacities are hard to be quantified and even harder to be modelled or numerically expressed. Therefore, the expert judgment for the adaptive capacities in the present will be used
6. Stakeholder consultation
7. Mapping of the vulnerabilities and the potential impacts
8. Identification of priority actions that address climate-driven vulnerabilities and gender-disaggregated impacts.

The following indicators are analysed:

- Growing season length (GSL)

- Crop yield for maize wheat in the base case (1971-2000) and two future scenarios (2011-1040 and 2041-2070)

- Crop yield for winter wheat in the base case and two future scenarios (2011-1040 and 2041-2070)
- Crop yield for potato in the base case and two future scenarios (2011-1040 and 2041-2070)
- Crop yield for tomato in the base case and two future scenarios (2011-1040 and 2041-2070)
- Crop yield for the grape in the base case and two future scenarios (2011-1040 and 2041-2070)
- The yield response to climate change for maize, winter wheat, tomato, potato and grape, as quantification of the vulnerability in percent.

- Impact of climate change
- Vulnerability Assessment
- Effect of adaptation measure irrigation and its effects in baseline period (1971-200) and two future period (2011-1040 and 2041-2070) for winter wheat, maise, potato and tomato crops.

Executive summary

Montenegro has a surface area of 13,812 square kilometres, which represents 0.35% of the EU. Agricultural land accounts for 38% (517,000 ha) of the total territory. Covering a relatively small area and benefiting from a Mediterranean climate, Montenegro's agriculture is quite diversified – from growing olives and citrus fruits in the coastal region, to early seasonal vegetables and tobacco in the central areas and extensive sheep breeding in the north[1]. Out of the total agricultural land, the largest percentage are meadows and pastures, which indicates the unfavourable structure of the use of agricultural land.

Agriculture is by far the largest activity of the rural population – more than 60,000 households obtain their income partly or entirely from agriculture[2]. Processing of agricultural products in high value and longer shelf-life products is still not on a sufficient level.

A number of positive trends are noticed in the agricultural sector for the period from tear 2015 to year 2020. This period is reported by the Statistical office of Montenegro (Monstat), and even for such a short period the trends are visible. The total agricultural utilized land increased by 11,5% (from 231405 ha to 257950 ha), utilized kitchen gardens and/or gardens increased by 9,5% (from 1861 ha to 2038 ha), utilized arable land increased for 2,9% from (6853 to 7055 ha), and vineyards increase by 6,6% (from 2708 ha to 2888 ha).

The livestock production is quite important in Montenegro. The agricultural land use presented above is based on huge predominance of pastures and meadows, that are basis for livestock production. There is obvious trend of increase in the number of heads of poultry by 34,6%, number of sheep by 19,3%, pigs by 17,1% and bovine by 11,3%.

Despite changes in production and productivity there are some important structural changes that can influence adaptive capacities, and therefore affect the vulnerability to climate change. The trends are determined by comparing data from AC 2010 with FSS 2016. Namely, utilized agricultural area increase by 15.6% (from 221297,6 ha to 255845,8 ha), the number of farmers reduced by 10,4% from 48870 to 43791, class size of the utilized agricultural land shows positive movements by reducing the number of small farms below 1 ha by -31% and significant increase for the bigger farms 139% for farms sized 5-10 ha and 129% for the farms with size 10-100 ha. All these changes can have positive impact on the production. However, the percentage of the farmers aged 55 and more years increase from 43 to 46% for only 6

[1] https://agriculture.ec.europa.eu/international/international-cooperation/enlargement/candidates_en

[2] https://agriculture.ec.europa.eu/international/international-cooperation/enlargement/candidates_en

years that can be considered as sign for aging of the agricultural population, which may have negative impact on the sector.

There are no formally established climate adaptation planning processes relevant for the sector agriculture. The coordination and the adaptation planning are done on an ad-hoc or project driven bases, with no clearly defined stakeholders, roles and responsibilities.

There are number of adaptation measures presented in the national documents (for agricultural sector, as in the TNC. However, there is not much clarity and transparency on the process, the approach (top-down, bottom-up, or integration of both approaches), and of evidence on consultative activities. The climate adaptation planning processes and the cross-sectoral policy coordination for the sector agriculture is also not considered in the Law on climate protection, neither in the Climate Strategy up to 2030. The Strategy for development of the agriculture and the rural areas considers climate change and climate impacts, but it defines only one specific measure related to renewable energy as a measure for low carbon and climate resilient economy.

It can be generally concluded that the key national policies in Montenegro dealing with climate change the Law on Protection against Adverse Impacts of Climate Change and the National Climate Change Strategy until 2030 are lacking the gender dimension, where the Law (Art.3) declares the usage of gender sensitive language, and the Strategy recognizes the international criteria (UNFCCC) in development of the improved adaptation plans, but still, without clear and precise mechanisms and tools provided.

Gender represents a complex social issue leading towards unequal positioning of women and men in the climate change processes (negative impacts, vulnerability, mitigation, adaptation) which must be firmly addressed into the climate change policies.

Agricultural production is very sensitive to climate. Agriculture is an activity usually conducted in an open area (open field production), therefore highly exposed to weather events. Moreover, the sensitivity is also high, and yield fluctuates from year to year mainly due to external factors.

Increased temperature seriously affects the agricultural systems. The crops grow faster, and the growth stage duration is reduced, thus less biomass is produced and accumulated, which usually results in lower productivity. Moreover, crops require more water for their normal growth, and crop water requirement (CWR) will be even more pronounced which can result in highly increased Irrigation water requirement (IWR) in case of reduced rainfalls as a major source of water for crop growth.

Montenegrin agriculture is limited by water and irrigation is quite common practice. The problem is that agriculture in the country is not enough adapted even in the present climate, therefore problems in future climate will be even alleviated. One of the most important problems is the lack of adaptation capacities, explained that crop yields are among the lowest in Europe. The reason for this can be associated with unfavourable environmental conditions for crop production (low fertile soils, the climate is hot with a number of dry periods during the growing season, etc.), as well as number of structural and social problems such as small farms with low capacities for investments, small plots which are hard to be modernized, the low economic power of the farmers, low level of education, aging of the farmer's population, etc.

The livestock production is also to a large degree performed outdoor, so animals are exposed to the weather effects. Moreover, the low-quality barns and buildings that do not provide proper sanitation, protection, from the sun and the heat, ventilation, etc., can have a negative effect on the animals, accelerate the heat stress and reduce productivity. Therefore, the impact of the climate on the productivity of agriculture is expected to be even more significant in the future.

Managing the impacts of climate change on Montenegrin agriculture is an interdisciplinary challenge that may be most effectively addressed using systems research strategies to integrate and develop disciplinary knowledge. For example, climate change can impact the livestock sector along a number of pathways: directly through impacts on productivity and performance and indirectly through price and availability of feed grains, competition for pastureland, and changing patterns and prevalence of pests and diseases. Therefore, it is highly connected to crop production impact, and the two sectors are strongly linked to fodder production.

The impact of environmental factors can be divided into 4 main groups **impact on soil**, including organic matter loss and erosion and reduced fertility, **impact on crops** including crop response to changes in agro-environment, yield reduction, new diseases, and pests; **Impact on livestock** including Reduced productivity and New diseases and pests, reduced animal welfare and **Impact on rural well-being** including reduced farm income, Increased cost of the production, Reduced economic power of the farms and Reduced interest for farming.

When it comes to the vulnerability of the sector Agriculture, the conclusions of all national communications on climate change related to the vulnerability of the sector agriculture, as well as the observation of the experts in charged for the development of this assessment are grouped as it follows:

- Montenegro is provisionally divided into five production regions: Coastal Region, Zeta and Bjelopavlici Region, Karst Region, Polimlje-Ibar Region, and Northern-mountainous Region. The most important crops are grapes, vegetables, potatoes, and fruits, while cereals and industrial crops (sugar and oil crops) are almost not present in the cropping pattern. Moreover, the document emphasizes livestock as the most significant branch of agriculture, participating with more than 60% of the total value of agricultural production.
- Soils are vulnerable to climate change, due to the increased temperature, and increased rainfall intensity that accelerates soil erosion and soil organic matter losses. The best quality soils are located in the river valleys, karst fields, and plateaus. The relief of the Montenegrin terrain is characterized by steep slopes above 10^o (65% of the territory), while slopes between 5^o and 10^o account for 28%. Only 7% of the territory has slopes that are less than 5^o, thus enabling the intensive use of land resources in agriculture without any significant consequences regarding erosion. Around 300 torrential basins are seriously affected by erosion; the volume of transported deposits exceeds 2 million m^3 per year. Land degradation neutrality is pointed out as one of the important factors in reducing the soil's vulnerability to CC. The analysis of the soil temperature is significantly improved and shows that in the last period the soil temperature is rising faster than usual. Moreover, the phenological data presented prove that flowering (crop growth stages) is shift several days earlier compared to the base period 1961-1990.
- The growing season length is increasing, and for the near future shows an increase by 11 days in the mountains with higher altitude, 18 days in the lower regions, and only by 3 days in the coastal region. However, due to the increased variability in climatic data, it is quite hard to recommend the effective use of the prolonged growing season due to the risk of early autumn and/or late spring frosts. The vulnerability assessment deals with the weather indices and emphasizes that despite the growing season being projected to be longer, frost damages are quite possible and earlier sowing is not an option due to the possible yield loss.
- Particular attention is given to the drought and Drought Management Center of Southeast Europe as a source of information and know-how in drought management. Moreover, drought is emphasized as the highest priority and main limiting factor of crop production. It is evident that Montenegro invested a lot of effort in drought assessment and the National Drought Plan of Montenegro recommends the Drought Watch platform for drought analysis. This clearly indicates that drought is considered one of the most important problems in the country and frequently and heavily affects agriculture and reduces productivity. The drought-vulnerable areas are Zeta River

Valley, the Bjelopavlići Plain, and the coastal area (slight to moderate vulnerability). The West coastal area is emphasized as the most vulnerable area.

- The floods are causing severe damage to crop production and sometimes disturb soils that will be deposited by flooding material.
- The livestock is affected by reduced fodder availability due to drought and heat stress as a result of increased temperature and more frequent and longer heat waves and floods due to difficulties for livestock evacuation. Moreover, the increased temperature disturbs the environment in the barns and buildings livestock is accommodated, the heat stress became pronounced and reduces productivity.
- The increased temperatures change the thermal conditions and some regions get characteristics of the thermal regime of the south. The new environment creates favorable conditions for some pests and diseases to move from South to North. Therefore, new pests and diseases can create serious problems with agricultural production because farmers are not familiar with their symptoms, treatment, and management practices. Montenegro is also vulnerable to the following new pest and diseases which were determined in the recent period:
    - Tuta Absoluta - Tomato leafminer was detected for the first time in Montenegro using pheromone traps in the middle of July 2010, in greenhouses in one location on the Montenegrin sea coast (Hrnčić, S., & Radonjić, 2014)
    - Lumpy Skin Disease is an infectious disease in cattle caused by a virus of the family Poxviridae, also known as Neethling virus, it first appearance in 2016 in Gusinje, Montenegro stopped meat export due to this disease (www.vijesti.me)
    - Bluetongue disease is a noncontagious, insect-borne, viral disease of ruminants, mainly sheep and less frequently cattle, first appearance in 2001 in region of Rozaje (Duric et al, 2004) with later outbreaks in 2014 and 2020.

In addition to the sectoral vulnerability, the following aspects are strongly defining the defining gender vulnerability in the agriculture sector:

- In the agricultural sector, women generally have less control over land and livestock (ownership), much less use improved seeds, quality fertilizers and banking services such as credits and loans, which means they have a smaller share in the use of extension services/measures[3].

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[3] https://klimatskipromeni.mk/data/rest/file/download/8327844cef4cb554e67b90d99397aa76d417246b2f3ade61f74575a6c07575c1.pdf

- Caring for dependent family members prevents women from being more present in the labor market, but the infrastructural (in)accessibility and remoteness of social, health, and educational services make their work at home even more difficult since it takes a lot of time to reach these services
- Women have traditionally been the guardians of cultural heritage and knowledge on the use of natural resources in health treatment/healing, cooking, etc[4].
- They are increasingly involved in vegetable production but are also involved in the production of dairy products, i.e. processing of dairy products, fruits, and vegetables[5]
- They are less represented in natural resource utilization activities such as forestry, hunting, fishing[6]
- Women are less represented in decision-making processes at the local level (and less informed about local policies).
- The educational structure and access to education for rural women is an important factor in strengthening the role of women in agriculture
- Women have less access to information on new technologies in both mitigation and adaptation.

In the framework of this assignment, modelling of the future climate change impact on the sector agriculture has been done. The important analysis of climate change is the yield response to the changing climate. The yield modelling was conducted for the baseline period 1971-2000 and the yield modelled for the period was used as a base case and compared to the two periods in the future (near future 2011-2040 and mid-future 2041-2070. The results presented below are relative differences in yield obtained during the modelling, using the FAO Aquacrop model.

A total of 5 crops were modelled to assess the effects of climate change on crop production in Montenegro. Maize is representative of the crops with a C4 photosynthesis pathway that is by far more tolerant to the increased temperature and increased water deficit than winter wheat, which represents crops with a C3 photosynthesis pathway. The response of these

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4 https://klimatskipromeni.mk/data/rest/file/download/8327844cef4cb554e67b90d99397aa76d417246b2f3ade61f74575a6c07575c1.pdf

5 https://klimatskipromeni.mk/data/rest/file/download/8327844cef4cb554e67b90d99397aa76d417246b2f3ade61f74575a6c07575c1.pdf

6 https://klimatskipromeni.mk/data/rest/file/download/8327844cef4cb554e67b90d99397aa76d417246b2f3ade61f74575a6c07575c1.pdf

cereal crops to climate change can be used as an indication for most of the C4 and C3 crops. Three additional crops considered important in Montenegro's agricultural sector were implemented in modelling activities. The first one is the potato which is widely grown on arable land (1707 ha in 2020) and in the kitchen gardens (547 ha in 2020) which is about 2250 ha in the year 2020 (State statistical office). The second one is tomato, the crop that is selected as representative of the high-yielding vegetable crops. Moreover, tomato is a crop that requires intensive cultural practices, and usually cannot be grown without irrigation. The tomato for the period 2015-2020 is planted on 138 ha and the average yield is 33 t/ha. The last crop is the grape which is probably the most important crop in Montenegro, considering the area and economic impact in the sector.

In addition to modelling of the impact on the crop production, assessment on the future impacts of climate change on livestock and beekeeping and been made.

Based on the analyses conducted, modelling activities and experience in the region we can say that Montenegrin agriculture is quite vulnerable on climate change. Even though Montenegro is a small country the relief is very diversified and there are 3 different zones, a coastal zone that is the typical Mediterranean, a middle zone with the influence of Mediterranean and mountainous climate, and a north part with continental mountainous influences. While coastal and central zone with changing climate is going to lose suitability for agricultural production as existing in present, the north region is going to heat much faster and to change the climate too much more favourable for growing present crops. Therefore, while adverse effects will happen in the south and central zone, the north zone is going to have much better suitability for crops. The logical response will be to move crops northward and toward higher elevations and to put the crops back in more suitable conditions. But this can work only on paper. Climate suitability is only one part of the agricultural system. The problems will appear with land availability, soil suitability, terrain, relief etc. Moreover, moving crops to other locations will disturb all value chains, disconnecting suppliers from their customers, the processing industry from agricultural products, extension officers from farmers, livestock farms from fodder sources etc. However not reacting will make all regions face climate change impact. The better suitability for maize growing in the north does not mean that their traditional cropping system will benefit. Likely the existing agricultural system in the north will be disturbed similarly to the system in the south and central part.

Livestock production will be also highly affected, heat stress is just part of the problem. There will be less fodder, less water available risk of new diseases, reduced profitability, and many other problems. Moreover, the Montenegrin traditional "katun production" will be disturbed by increased heath, possible reduction of grasses productivity, and eventual changes in floristic compositions of the pastures and natural meadows.

However, we should take into consideration that the vulnerability of the entire sector can't be evaluated with only one assessment, and this report is focusing on the general climate change impact and the specific impact on few representative crops (maize, winter wheat, potato, tomato and grape), dairy cows as representative of the livestock populations and touches upon the vulnerability of the sector beekeeping (which is a separate category and is not considered as part of the agricultural production). The capacities should be further developed, and similar assessment should be conducted on a level of municipality, which will enable a detailed assessment on location specific climate vulnerabilities and will produce a much more appropriate list of adaptation measures which will address the local problems and vulnerabilities.

Adaptation options and measures are something that should be carefully elaborated and tested in the national environment, and farmers should be informed on optimal adaptation practices they should use in a given situation. Clearly, late spring frost, summer drought, and new pests required totally different solutions, therefore different adaptation practices should be applied. Therefore, serious research activities, experimental fields, and plots for testing and spreading the adaptation measures and training programs for agricultural operators should be conducted. The best solution will be to establish the Center for climate change research, technology transfer, and training in the frame of the existing institutions with research capacities in climate change in agriculture.

The first adaptation option for Montenegro will be building the adaptive capacities on the individual, institutional, and system levels in order to create a more resilient agricultural system in the country. Capacity building should not be an awareness raising, the number of stakeholders clearly know what climate change is. They need to understand the scale of the problem, links between climate, agro climate, cropping practices, management, and market, and to be ready to implement adaptation practices. Moreover, this process has to be accompanied by the process for support and investment in adaptation practices. More specific and gender responsive priority actions for addressing climate driven vulnerabilities are also provided in the last chapter of this report, and these actions should serve as a basis and inform the national and the local climate adaptation planning processes.

1. Overview of the national circumstances relating to the sector Agriculture

1.1. Geographic profile relevant for the sector

Montenegro has a surface area of 13,812 square kilometers, which represents 0.35% of the EU. Agricultural land accounts for 38% (517,000 ha) of the total territory. Covering a relatively small area and benefiting from a Mediterranean climate, Montenegro's agriculture is quite diversified – from growing olives and citrus fruits in the coastal region, to early seasonal vegetables and tobacco in the central areas and extensive sheep breeding in the north. Out of the total agricultural land, the largest percentage are meadows and pastures, which indicates the unfavorable structure of the use of agricultural land.

Agriculture is by far the largest activity of the rural population – more than 60,000 households obtain their income partly or entirely from agriculture. Processing of agricultural products in high value and longer shelf-life products is still not on a sufficient level.

The average size of utilised agricultural land per holding is 5.8 ha, but it is important to underline that 72% of agricultural holdings are 2 ha in size or less. The farm structure is dominated by small family farms, which produce mainly for their own consumption. Out of the total of 43,791 agricultural holdings in Montenegro (2016), 31,260 or 71.4% agricultural holdings breed livestock and/or poultry. The number of these agricultural holdings decreased by 4.3% compared to the number of livestock holdings in 2010.

For countries such as Montenegro, where the main drivers of agriculture are family farms, they represent an important economic factor in the development of agriculture. The most unfavorable fact of the influence of agricultural farms on the development of the sector agriculture is manifested in their relatively small land areas. Agricultural land in Montenegro accounts for 16% of the total area. According to the data of the Census of Agriculture, in 2010 the average agricultural farm had 4.6 ha of agricultural land, while the data from 2016 show that it amounts to 5.8 ha, which indicates the enlargement of holdings.

In Montenegro, according to the 2010 Census of Agriculture, the total irrigated area was 5,204.2 ha, which is 10.8% of the total used agricultural land. The total number of agricultural holdings which use irrigation was 12,518, which means that the average area that one agricultural holding irrigates is 0.42 ha. The highest percentage of irrigated area in relation to the production area is in vineyards. Namely, 96.2% of the total area under vines is irrigated, and the least irrigated areas are under perennial meadows and pastures (only 0.11% of the total area of meadows and pastures).

1.2. Socio-economic trends in the sector

Of the total employees in Montenegro about 1.5% of the workforce is engaged in the food industry. There are more than 300 food producers of large and medium capacity. In the production of dairy products, meat and in the sector wine production, the largest volume is concentrated in several large companies, although there is significant number of small manufacturers and family-owned production facilities. Regarding fruit and vegetables, as well as olives, the production is fragmented with a number of small producers who doesn't have competitive strength on the market.

When it comes to the national food market, it is necessary to emphasize that the domestic food production is insufficient for the domestic food demand, and the food imports are far higher than the food and the agricultural products exports. As for value-added products such as traditional, indigenous and organic products the limited quantities of these products are an obstacle to their success marketing.

Table 1 Agricultural land structure and (in ha), Montenegro

Year	Total agricultural land (ha)	Arable land (ha)	Gardens and yards(ha)	Permanent plantations (ha)	Perennial meadows and pastures (ha)
2015	231,405.4	6,853.3	1,861.1	5,057.9	217,633.1
2016	255,845.8	7,103.9	1,922.4	5,486.3	241,333.2
2017 p	256,361.2	7,162.6	2,003.8	5,470.4	241,724.4
2018 p	256,807.7	7,199.6	2,014.3	5,480.9	242,112.9
2019 p	257,469.6	7,204.6	2,009.8	5,537.7	242,717.5
2020	257,949.8	6,964.6	2,063.6	5,674.9	243,246.7

Source: Statistical Office of Montenegro (Monstat)

The analysis of changes in the area of used agricultural land shows growth, observing the period from 2015 to 2019, which is presented in the table above. The total agricultural area used in 2015 was 231,405.4 ha, and in 2019 257,469.6 ha, which indicates an increase of 11.3%. A similar case is with arable land. In 2016, averagee agricultural holding had an area of 5.8 ha of used agricultural land. In 2010, that average was 4.5ha. Utilized agricultural land in 2020 is 257 949,8 ha, what is an increase of 0.2% compared to 2019. In total utilized agricultural land areas, perennial meadows and pastures areas prevail with the share of 94.3%, while arable land are present with 2.7%, permanent crops 2.2% and kitchen gardens 0.8%. In comparison with 2019, perennial meadows and pastures area increased by 0.2%, permanent crops increased by 0.2%, kitchen garden 1.4%, while arable land decreased by 2.1%.

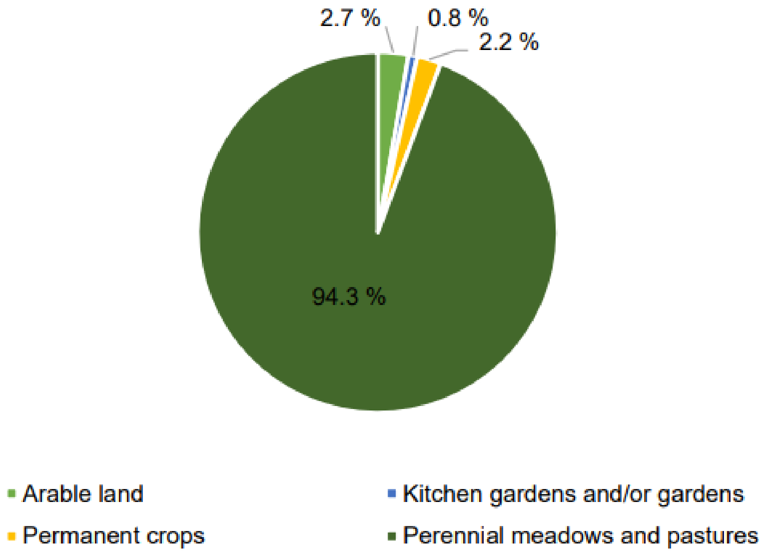


Figure 1 Utilised agricultural area, 2020

Total production of potato in 2020 was 39 301.9 t, which is an increase of 10.8% compared to 2019. An increase in production was also recorded in the following crops: wheat (4.3%), dry beans (16.1%), cabbage (11.9%), cucumber (11.3%) and pepper (4.5%). Compared to 2019, an increase is recorded in total production of: plums (16.8%), apples (15.7%), pears (16.7%), peaches (21.0%), while there was recorded lower production of: olives (4.2%) and mandarins (6.9%). The total production of grapes in 2020 records an increase by 3.9% in comparison with previous year.

The value of the purchase and sale of the agricultural, forestry and fishery products by business entities and agricultural cooperatives with two and more employees in the first quarter of 2022 was 5.1 million EUR[7], from which the value of the sale of the own production of business entities was 1.8 million EUR or 35.3%, while the value of the purchase from individual agricultural producers was 3.3 million EUR or 64.7%. The value of the purchase and

[7] https://www.monstat.org/eng/novosti.php?id=3518

selling of the agricultural, forestry and fishery products by business entities and agricultural cooperatives with two and more employees, decreased in the first quarter of 2022[8] comparing to the same quarter of previous year for 7.6%, from which the value of own production of business entities increased for 1.3%, and the value of purchase of agriculture products from individual producers decreased for 11.8%. In the structure of the value of purchase and selling of agricultural, forestry and fishery products in the first quarter of 2022 participate row cow milk with 28.9%, hen's eggs with 21.1%, livestock by types and categories with 13.3%, vegetables with 12.8%, other products with 7.4%, fresh fish with 7.1%, industrial crops 3.9%, fruit with 3.2%, and processed fruit and grapes with 2.3%

The growth in agriculture sector in the period 2022-2024 is projected at 8.0 percent, and is based on increased investments in agriculture, with substantial budgetary support to this sector. It is expected that the improvement of competitiveness of agricultural producers will lead to reduction of food imports through the substitution and/or growth of exports.

The total number of cattle in 2020 is 77 889, which compared to 2019 represent decrease of 4.4%. In 2020, the total number of sheep were 176 580 and compared with 2019 represent the decrease by 3%, while the total number of goats were 27 823 and is decreased by 3.2%. The number of pigs in 2020 is 25 806 and recorded an increase of 11.8% compared to 2019, while the number of poultry recorded a decrease of 5.4%.

In the diagram below it is shown the structure of Agri-food trade of Montenegro with EU for the period of 2011-2021.

[8] https://www.monstat.org/uploads/files/poljoprivreda/otkup%20i%20prodaja/2022/1/Purchase_%20and_%20sale_%20of_%20agricultural_%20forestry_%20and_%20fishery_%20products_%20I%20quarter_%202022.pdf/

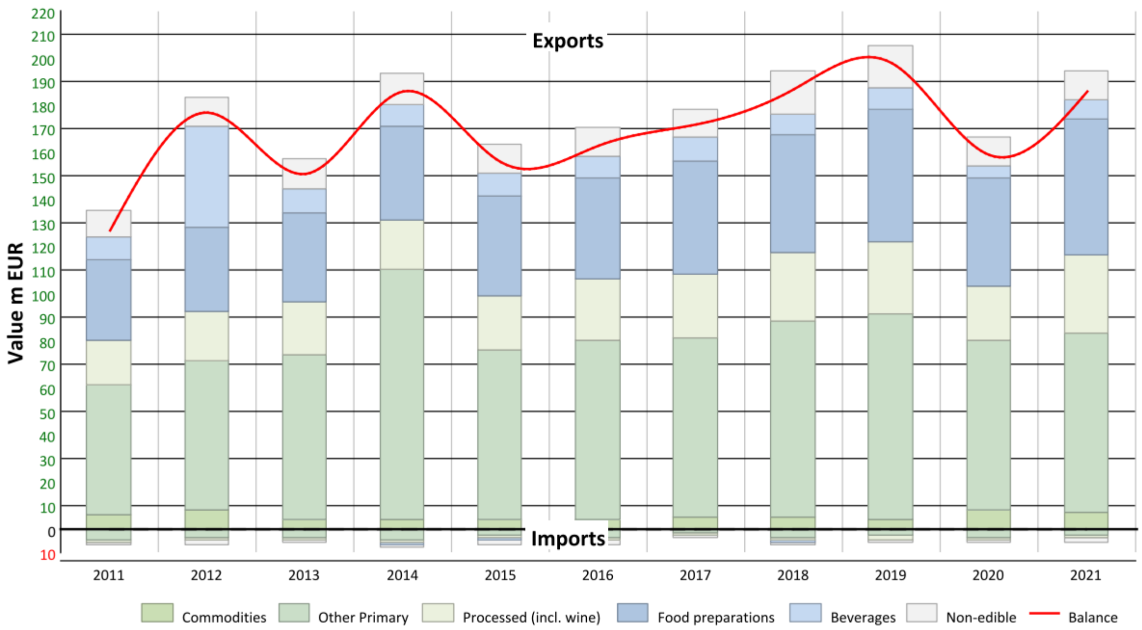


Figure 2 Structure of EU Agri-Food trade with Montenegro, 2011 - 2021

1.3. Sectoral trends

A number of positive trends are noticed in the agricultural sector for the period from tear 2015 to year 2020. This period is reported by the Statistical office of Montenegro (Monstat), and even for such a short period the trends are visible. The total agricultural utilized land increased by 11,5% (from 231405 ha to 257950 ha), utilized kitchen gardens and/or gardens increased by 9,5% (from 1861 ha to 2038 ha), utilized arable land increased for 2,9% from (6853 to 7055 ha), and vineyards increase by 6,6% (from 2708 ha to 2888 ha). However, the highest increase of the area is noticed for orchards plantations by 21,5% (from 1145 ha to 1391 ha), while extensive orchards increased by almost 5% (from 1147 ha to 1204 ha), The data for orchards (plantation and extensive) includes olive trees as well. The total increase of the orchard area (plantation and extensive) is about 303 ha and most of this area (246 ha or 81,2%) are plantations, that give signs that the sub-sectors of fruit growing is the most dynamic one and slightly moving toward more intensive, organized and modern production on plantations. The biggest portion of the increased orchards area is with apples (increase of 77ha), plums (increase by 65 ha, olives (increase by 63 ha) and mandarins (increase by 25 ha). These positive trends are moving fruit and olive production to become even more important subsector in Montenegrin agriculture. These increases in the orchard area can be associated with increase of area under nurseries and increase of the locally production planting materials. Nurseries area increased by 18% (from 58 ha to close to 69 ha).

Finally, the most important category of agricultural land use are perennial meadows and pastures that covered about 94,3% of the total agricultural utilized land in the country. The positive trend is also noticed for perennial meadows and pastures, that increase by 11,8% (from 231405 ha to 243304 ha).

The livestock production is quite important in Montenegro. The agricultural land use presented above is based on huge predominance of pastures and meadows, that are basis for livestock production. Moreover, the cropping pattern show that forages (lucerne, clover, grass-clover mixtures and grass mixture) are quite important in the country, ranged just after potato in area harvested with more than 1400 ha. Therefore, the livestock production is important for utilizing the production of crops which are essential for livestock breeding. The trends in livestock production are determined by the comparison of the data collected by MONSTAT in 2010 (Agricultural census AC 2010) and 2016 (Farm Structure Survey – FSS 2016). The data is presented in following table.

Table 2 Number of livestock and changes for the period 2010 and 2016

Type of livestock	**2016**	**2010**	**Change in%**	**Changes in number of heads**
Bovine	**89269**	**80209**	**11.3**	**9060**
Sheep	**229037**	**191992**	**19.3**	**37045**
Goats	**31458**	**35756**	**-12.0**	**-4298**
Pigs	**55841**	**47673**	**17.1**	**8168**
Poultry	**835705**	**620802**	**34.6**	**214903**
Horses, asses, mules	**3947**	**4397**	**-10.2**	**-450**

Source: Monstat Agricultural Census (2010) and Farm structure survey (2016)

There is obvious trend of increase in the number of heads of poultry by 34,6%, number of sheep by 19,3%, pigs by 17,1% and bovine by 11,3%. The reduction by 12% and by 10,2% id determined for goats and horses, asses and mules, respectively. Important trend in livestock sector is related to the structural changes in scale of the farms, and reduction of holdings with bovine production while number of heads increase, therefore, the farms are trending to become bigger.

Table 3 Agricultural holdings with bovines by class sizes of herd

Agricultural holdings	Number of holdings	Class size by total number of bovines							
		No bovine	1 – 2 heads	3 – 9 heads	10 – 19 heads	20 – 29 heads	30 – 49 heads	50 – 99 heads	100 heads and over
FSS 2016	43791	21852	11684	8512	1444	179	76	32	12
AC 2010	48870	24246	15024	8512	917	91	52	21	7
Changes in %	-10.4	-9.9	-22.2	0.0	57.5	96.7	46.2	52.4	71.4

Source: MONSTAT, Farm structure survey (2016) and Agricultural Census (2010)

Data in the table presents that number of very small farms with 1-2 bovine decreased by 22%, there is no changes for the farms with 3-9 heads. All other size classes increased by about 50%, while biggest farms with more than 100heads increased by 71,4% and maximal increase is recorded for farm size of 20-29 heads by 96,7%.

Despite changes in production and productivity there are some important structural changes that can influence adaptive capacities, and therefore affect the vulnerability to climate change. The trends are determined by comparing data from AC 2010 with FSS 2016. Namely, utilized agricultural area increase by 15.6% (from 221297,6 ha to 255845,8 ha), the number of farmers reduced by 10,4% from 48870 to 43791, class size of the utilized agricultural land shows positive movements by reducing the number of small farms below 1 ha by -31% and significant increase for the bigger farms 139% for farms sized 5-10 ha and 129% for the farms with size 10-100 ha. All these changes can have positive impact on the production. However, the percentage of the farmers aged 55 and more years increase from 43 to 46% for only 6 years that can be considered as sign for aging of the agricultural population, which may have negative impact on the sector.

2. Overview of the climate adaptation planning processes in Montenegro

2.1. Overall climate adaptation planning process

The assessment of climate adaptation in the relevant sectoral and climate protection legislation has concluded that there is no legally established framework for climate adaptation planning in the country, despite the existence of various Laws and planning processes that somehow relate to climate change adaptation. The assessment has resulted in the following specific conclusions:

- The Law on climate protection of Montenegro (Article 5) recognises the National Adaptation Plan (in the further text NAP) as basis climate planning instrument and defines the minimum content of the NAP.

- According to the prescribed minimum content of the NAP in the Law (Article 9), the NAP would also need to define the institutional framework for climate adaptation in the country.

- The Law doesn't prescribe mechanisms for cross-sectoral policy alignment and mainstreaming of the adaptation priorities in the sectoral policies and plans.

- The Law doesn't prescribe climate change coordination mechanism as for example National Climate Change Committee, Climate Council or Sustainable development council.

- The Government of Montenegro (GoM) supported by international organisations have taken steps to develop a long-term adaptation planning process in the process of the preparation of the National Climate Change Strategy by 2030 and the preparation of the Third National Communication. However, all these processes have been project based and haven't been institutionalised and legally established.

- The National Climate Strategy by 2030 has been prepared in 2013 and its content is not aligned with the latest EU requirements for long term strategic planning for climate action defined in the Regulation 1999/2018 (the Energy Governance Regulation).

- Despite the fact that the National Climate Strategy by 2030 has adaptation aspects into its content, the document only provided an overview of the internationally recommended approaches for climate adaptation and provides information on the preparatory elements and the processes essential for the development and implementation of the NAP. The table containing the preparatory elements and the process for development and implementation of the NAP is well elaborated, but it is general for all sectors, and it doesn't set clear responsibilities for specific institutions, timelines and institutionalised coordination mechanism needed for implementation of such steps in a form of a specific action plans.

- In addition, the National Climate Strategy by 2030 provides an overview of the proposed adaptation measures by sectors as defined in the draft Second National Communication, which are not sufficiently described, and the process of identification of the vulnerabilities and definition of this measures is not elaborated.

- The TNC of Montenegro prepared in 2020 in its Sector vulnerability and adaptation analysis provides very clear recommendation that the priority activity for climate adaptation is the strengthening of the strategic planning for climate change adaptation at the local and regional levels, as well as in the sector-level planning process. In addition the TNC recommends this to be accomplished through the development of action plans for climate change adaptation at the local and regional levels, development of action plans for climate change adaptation of vulnerable sectors, integration of adaptation measures in strategic and development documents, preparation of plans for the prevention of climate change impacts in sectors vulnerable to climate change, and through the development of methods and standards for implementation of adaptation measures. Also, an additional proposed measure is strengthening of local and regional governments and other relevant national, regional, and local stakeholders regarding climate change adaptation. These measures are very valid, but again, they don't describe and prescribe the national coordination mechanism for climate adaptation, the legal and the institutional aspects for establishment of such mechanism, as well as the processes and the responsibilities for climate change adaptation on national and local level.

- Despite the fact that in the framework of the TNC a vulnerability assessment and adaptation measures for all priority sectors has been done, the adaptation planning process done in the framework of the preparation of the TNC is not prescribed and responsible stakeholders and processes for coordination, elaboration, implementation and monitoring of the climate adaptation are not defined.

- Montenegro's Updated NDC provides a development framework and guidance for more ambitious adaptation goals to be developed under the project "Enhancing Montenegro's capacity to integrate climate change risks into planning". According to the Updated NDC, the goals defined by the NDC will have a clear effect on project activities focusing on addressing the gaps of an underperforming coordination framework, the lack of institutional capacity, the insufficient information and lack of finance to fund adaptation investments and will also improve the capacity of the private sector to understand and respond to climate vulnerabilities and risks.

Taking into consideration all conclusions listed above, one of priorities of the NAP Project should be to define, legally regulate and institutionalise the national climate adaptation planning processes.

2.2. Assessment of the sectoral planning process

There are no formally established climate adaptation planning processes relevant for the sector agriculture. The coordination and the adaptation planning are done on an ad-hoc or project driven bases, with no clearly defined stakeholders, roles and responsibilities.

There are number of adaptation measures presented in the national documents (for agricultural sector, as in the TNC. However, there is not much clarity and transparency on the process, the approach (top-down, bottom-up, or integration of both approaches), and of evidence on consultative activities.

The climate adaptation planning processes and the cross-sectoral policy coordination for the sector agriculture is also not considered in the Law on climate protection, neither in the Climate Strategy up to 2030.

The Strategy for development of the agriculture and the rural areas considers climate change and climate impacts, but it defines only one specific measure related to renewable energy as a measure for low carbon and climate resilient economy. Finally, the Ministry of Agriculture and Rural Development started to invest in building up the adaptive capacities to climate change. There is a number of measures implemented by the National program for the support of agriculture (Guide through Agrobudget for 2021, MARD) such as Support for sustainable management of the mountainous pastures, Support for manure management, Support for adaptation of the mountain Katuns, Support for purchasing irrigation equipment, protective nets, and foils, Support for the construction of new wells and reservoirs, Support for the purchasing of reel guns irrigation machines, Support for purchasing of water pumps, Support of the organic production and other. Moreover, the Instrument for Pre-Accession Assistance for Rural Development (IPARD) program supports activities for improvement of the living conditions in the villages. One of the measures supported is adaptation of the livestock housing, which can significantly reduce the heat stress of the livestock. The implementation of such measures will increase the adaptation capacity and the vulnerability of the sector will be reduced.

It can be generally concluded that the key national policies in Montenegro dealing with climate change the Law on Protection against Adverse Impacts of Climate Change and the National Climate Change Strategy until 2030 are lacking the gender dimension, where the Law (Art.3) declares the usage of gender sensitive language, and the Strategy recognizes the international criteria (UNFCCC) in development of the improved adaptation plans, but still, without clear and precise mechanisms and tools provided.

Gender represents a complex social issue leading towards unequal positioning of women and men in the climate change processes (negative impacts, vulnerability, mitigation, adaptation) which must be firmly addressed into the climate change policies.

Still, it can be concluded that the national policies in sectors related to climate change, key climate change documents and other related reports and national communications in Montenegro have a gender dimension by the following rule: the newer the document is, the bigger inclusion of the gender perspective is evidenced.

The intersection of gender and climate change policies must be strengthened in Montenegro, along with strengthening the institutional capacities on intersecting gender and climate change at policy development level, as well as implementation level, and accompanied by gathering sex-disaggregated data and development of gender indicators for the purpose of gender responsive measurement and verification of the climate actions.

3. Data constrains, gaps and reccomendations

3.1. Gaps in sectoral information for gender sensitive vulnerability assessment of the sector agriculture

The **statistical data on land use and crop production and productivity** is available from the web site of Statistical office of Montenegro. There are three major sources of data are:

- Data from Farm Structure Survey from year 2016 (FSS-2016)
- Data from Agricultural Census conducted in 2010 (AC-2010) and
- Data from Producing statistics (PS)

The following gaps are determined:

- **Non-sufficient spatial distribution of data available** Data is presented on country level, there is not publicly available data disaggregated on the smaller statistical units. Montenegro is characterized with diverse environmental condition on very small territory and analyse on country level will not provide sufficient information in different climatic zones

- **Non-sufficient temporal resolution** data from AC-2010 and FSSS-2016 present situation for only one year, 2010 and 2016 respectively. The PS data are distributed for the period 2015 -2020 (6 years period). However, amount of data for period from 2016 to 2020 is labelled with (p) that is label for preliminary data.

- **Non suitable data files** the AC_2010 data presents number of parameters disaggregated to the municipalities. However, data is distributed in pdf format and cannot be used for further analyses. Eventual file conversion and/or retyping can result with eventual errors in the datasets and eventual copyright problems.

The responsible institution for meteorological observation and handling for **climate data** is Institute of Hydrometeorology and Seismology of Montenegro. Data is presented on their web site[9].

The web site in the part for meteorology presents:

- Climate characteristics

[9] http://www.meteo.co.me

- Climate normal (monthly averages for the period 1961-1990 for 11 cities - Ulcinj, Bar, Herceg Novi, Cetinje, Podgorica, Niksic, Kolasin, Berane, Bijelo Polje, Zabljak, Plevlja)
- Extremes for same cities, for unknown time period and
- Reports, that are available in textual and graphical form for monthly seasonal (spring, summer, autumn and winter) and annual from year 2018 to present.

Moreover, the Agrometeorology subdivision from the Meteorology section of the web site presents data on:

- Ground temperature
- Phenology and
- Agrometeorological data report.

The drought subdivision from the Meteorology section of the web site presents data on SPI index, while the exposure map is not available.

The web site is very well designed and informative. However, there are some gaps that make the data presented not usable for modelling or any serious analyse in agriculture, related to the temporal resolution daily data is required for climate change modelling:

- **It is impossible to get any climate dataset** from the web site the climate datasets should be 30 years of daily data. Using the monthly averages number of risks will be neglected (frost damages, heat waves, heath stress and shorter drought periods)
- **Spatial resolution** – in number of cases spatial resolution do not work and cities presented on the map cannot be selected, required data is for all meteorological stations (main, climatological and rainfall) to get analyses with good spatial resolution
- **Data organization** – almost each chapter on the web site is differently organized. Copying the data from the web site and later retyping is not solution. Moreover, the data scraping is almost impossible.
- **Number of data is presented on maps** and without any attribute tables and metadata
- **There is not download section** and data is not freely available
- **Using of some not sufficiently informative indices** for drought analyse in agriculture, like SPI index for drought. The index is very good for meteorological drought assessment. The SPI index presents deviation from the standard precipitation that is excellent tool in meteorology. However, agricultural drought

is differently defined, and other indices are much more descriptive and better appreciated in agricultural sector.

Finally, there is number of reports that already analysed vulnerability and adaptation of the agricultural sector. These reports usually do not consider spatial distribution of the parameters analysed and results are presented in the form that is not usable for further analyses. The paper (or pdf) format does not provide possibilities to add anything new to the analyses and can be used only as copy/paste source. During the analyse of the data availability we did not determine any data portal related to the number of previous activities. Unfortunately, data used for previous analyses and results obtained are lost and/or converted in hardly usable paper/pdf format.

3.2. Recommendation for improved data collection and management of gender sensitive climate relevant data for the sector agriculture

The intersection of gender and climate change policies must be strengthened in Montenegro. This must be done with the strengthening of the institutional capacities on intersecting gender and climate change at policy development level, as well as implementation level, and accompanied by gathering sex-disaggregated data and development of gender indicators for the purpose of gender responsive measurement and verification of the climate actions.

Women are entitled to reforms for equal right to natural resources, ownership and control over land and other forms of property, economic opportunities and financial services by the National Strategy for Sustainable Development until 2030 , of Montenegro, and the in the area of Agriculture covered by the Strategy for Development of Agriculture and Rural Areas 2015–2020 of Montenegro (Ministry of Agriculture and Rural Development) female perspective is not present, and it is only tackled in the sex-disaggregated data shown in the Gender and Age Structure of the Workforce on Family Agricultural Holdings, which is not further considered into concrete measures, goals, activities etc. On the other hand, within the Programme for Development of Agriculture and Rural Areas of Montenegro within IPARD II 2014–2020, incentive measures for women from rural areas were implemented, in terms of modernization of holdings, strengthening of production competitiveness, increasing the productivity of holdings, reducing costs, increasing product quality, hygiene and food safety.

4. Findings on sectoral risks, vulnerabilities and impacts from the past and the present climate variability in Montenegro

4.1. Observed impacts on the sector Agriculture

The impact is a product of sensitivity and exposure, the higher the sensitivity or higher the exposure the impact will be higher.

Sensitivity

Agricultural production is very sensitive to climate. Agriculture is an activity usually conducted in an open area (open field production), therefore highly exposed to weather events. Moreover, the sensitivity is also high and yield fluctuates from year to year mainly due to external factors.

Increased temperature seriously affects the agricultural systems. The crops grow faster, and the growth stage duration is reduced, thus less biomass is produced and accumulated, which usually results in lower productivity. Moreover, crops require more water for their normal growth, and crop water requirement (CWR) will be even more pronounced which can result in highly increased Irrigation water requirement (IWR) in case of reduced rainfalls as a major source of water for crop growth.

Montenegrin agriculture is limited by water and irrigation is quite common practice. The problem is that agriculture in the country is not enough adapted even in the present climate, therefore problems in future climate will be even alleviated. One of the most important problems is the lack of adaptation capacities, explained that crop yields are among the lowest in Europe. The reason for this can be associated with unfavorable environmental conditions for crop production (low fertile soils, the climate is hot with a number of dry periods during the growing season, etc.), as well as number of structural and social problems such as small farms with low capacities for investments, small plots which are hard to be modernized, the low economic power of the farmers, low level of education, aging of the farmer's population, etc.

The livestock production is also to a large degree performed outdoor, so animals are exposed to the weather effects. Moreover, the low-quality barns and buildings that do not provide proper sanitation, protection, from the sun and the heat, ventilation, etc., can have a negative effect on the animals, accelerate the heat stress and reduce productivity. Therefore, the impact of the climate on the productivity of agriculture is expected to be even more significant in the future.

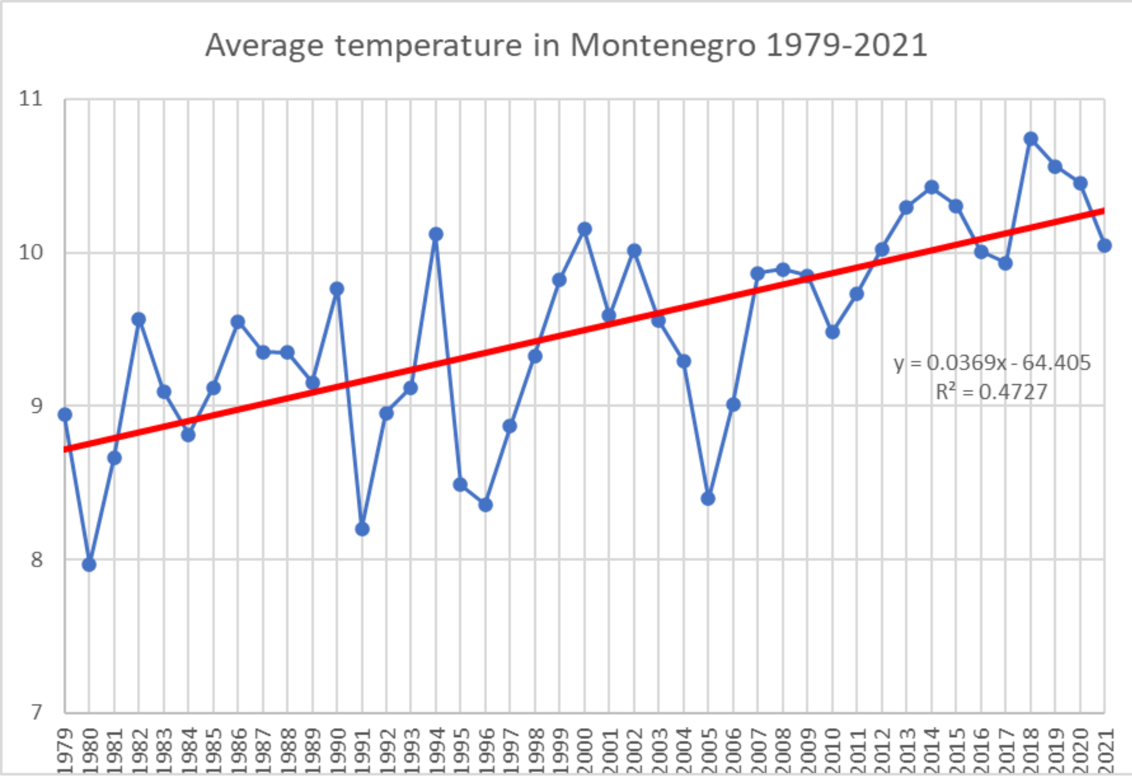


Figure 3 Average annual temperature in Montenegro, the average for all grids, JRC MARS Agrometeo dataset, period 1979-2021.

The figure above presents the average annual temperatures in Montenegro for the period 1979 – 2021. As seen from the Figure, the last 10-year period is the hottest in the observed period of 43 years.

The increased temperature will speed up the temperature accumulation, the growth stages will be accelerated and due to the short duration of the stages less biomass will be accumulated, However the increased temperature will increase growing season duration, and period favorable for crop growing will be longer and even longer part of the year will have favorable thermal condition for crop growing. Sometimes this longer period can be utilized by growing the high yielding hybrids with longer season, implement double cropping (two harvest in one year) etc. Recommending such measures to the farms when there is high confidence that extreme events (including late spring and early autumn frost) will be more frequent and more severe is very risky, particularly when based only on one indicator. The following map presents changes in growing season length as result of increased temperature in the future periods.

A		B

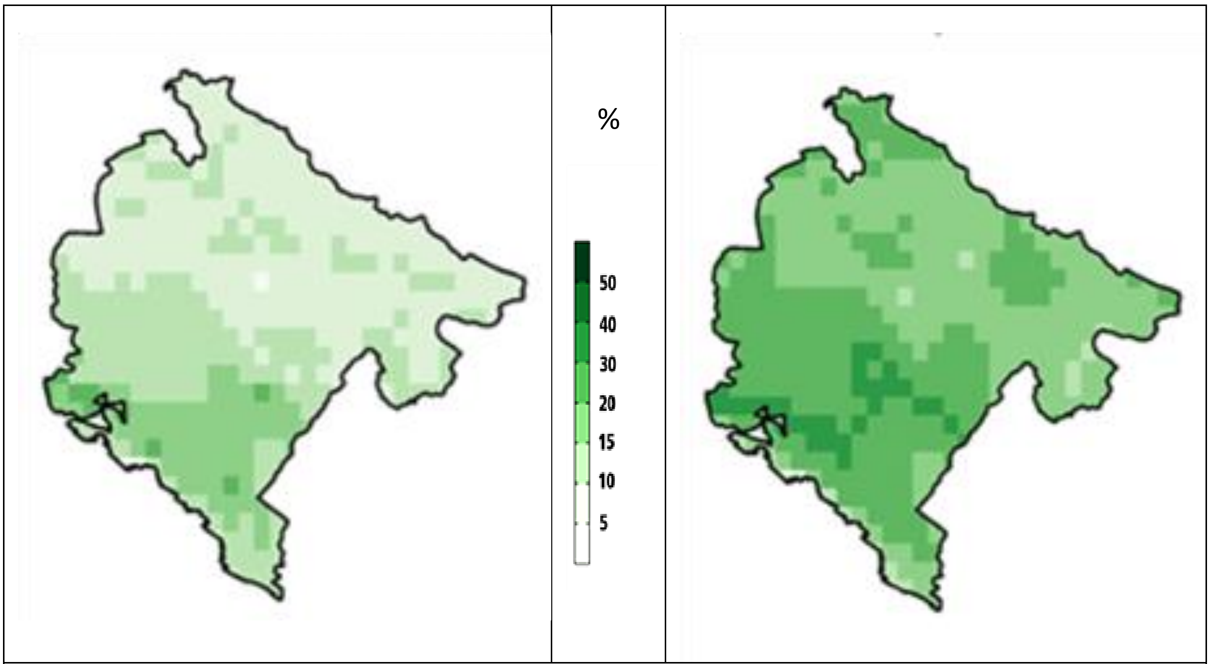


Figure 4. The average changes in the growing season length as result of climate change, the base period 1971-2000 compared to A. near future period 211-2040 and B. future period 2041-2070

According to RCP 8.5 (Realization Concentration Pathway), we can see that the length of the vegetation period will become longer as the end of the century is closer. During the period from 2011 to 2040, a positive change can be expected in the entire territory of the country and an increase in the length of the vegetation period from 10% to 20% in relation to the value during the period 1971-2000 (baseline), with higher values in the south. For the second period analyzed (2041–2070), changes are again more pronounced in the southern part of the country. During the period 2041–2071. most of the northern part of the country has a positive change of about 15%, while in some parts of the south the positive change is greater than 30% compared to the period 1971-2000.

Therefore, the conclusion is that the growing season will be longer, which will create more favorable conditions for the crops grown at higher altitudes. The second cropping season is feasible in the southern part, according to the growing season duration. However, crop production is limited by water shortage and the prolonged season cannot be considered as benefit (or positive impact of CC on the agricultural sector) without providing a sufficient amount of water for irrigation and infrastructure that can be a big challenge.

Irrigated land - the national strategy for the development of agriculture and rural areas for the period 2015-2020 pointed out that irrigation is essential for normal crop growth. However, there is no data on irrigated areas in the country. The strategy defines: Around 51,000 ha of land are suitable for irrigation, yet only 15-17% of this is actually irrigated.

Exposure

The annual temperature is increasing in the period from 1979-2021, based on the analyses of the JRC MARS Agrometeo datasets for all grids that overlap the Montenegro territory (partially or whole grid cell). The graph of the temperature rise is presented earlier. However, to better explain the variability of the temperature the statistical analyses of the climate period should be accompanied by statistical analyze. The period 1979 to 2021 is characterized by mean: 9.49°C; range 7,97 to 10,74; standard deviation 0,67 and coefficient of variation 0,07.

Annual rainfall also increases in the period from 1979-2021, based on the analyses of the JRC MARS Agrometeo datasets for all grids that overlap Montenegro territory. Also, to better explain the variability of the rainfall same basic statistic will be used, therefore, the period 1979 to 2021 is characterized by a mean: 1039,7 mm; a range of 499,1 mm to 1745,2mm; a standard deviation of 312,4 mm, and a coefficient of variation 0,30. Therefore, variation in the rainfall is quite higher than in the temperature. It will be good to have multiannual yields of various crops to compare them with temperature and rainfall variation.

Drought can be parametrized by a number of existing drought indexes. The previously used Standardized Precipitation Index (SPI) is maybe the most widely used index, but the index itself only presents an anomaly of the rainfalls from the Long-Term Average (LTA). Agriculture is not one parameter-based approach, and a number of parameters are used to explain ongoing processes; therefore, one parameter index is not really explanatory. There is a number of drought indices in agriculture and many researchers were looking for the best composition of the parameters to be used. A number of researchers used at least rainfall and temperature in the index they have developed. However, in the last period drought index as defined by UNESCO in 1979 and by UNEP in 1992 found a basis to be widely used in agriculture. The index divides annual precipitations with annual potential evapotranspiration. Such a ratio helps to understand how much of the evapotranspiration can be covered by natural rainfalls. UNESCO's proposal was to use the Penman formula for calculating the evapotranspiration and all areas with an index higher than 0,75 are considered as humid.

The period 1979 to 2021 is characterized by mean value of the aridity index of: 1,15; range 0,50 to 2,01; standard deviation 0,38 and coefficient of variation 0,18. The values presented here, are addressing the whole country's territory and values are higher because of the fact that average rainfall in Montenegro is high, but most of them are in high elevated areas. Agriculture usually is on lower land where the precipitation is much lower. **Extreme weather events** cannot be assessed without additional data, because the data is not considering hail and hail damage, storms, floods, and a number of events that reduce crop and livestock productivity. The report on the Future climate projections and analyses of the extreme weather and climate events prepared by Djurdjevic V. (2018) presented a number of extreme weather events related to the extreme temperature like the number of summer days, number of tropical days, heat wave duration index, number of heat waves as well as weather events related to precipitation as number of days with precipitation accumulation higher than 20mm, number of days with precipitation above 95 percentile, number of events with higher than 60mm of accumulated precipitation and some other.

Livestock heat stress: Addressing the negative consequences on livestock systems requires access to many technical solutions that are used to affect the farms' physical parameters. The technical solutions approach includes increased ventilation, air conditioning, air recirculation, and insulation to influence climate parameters such as air temperature, wind velocity, humidity, and conditions for radiation heat exchange. For the optimal outcome of those approaches, it is essential to know how the animals would respond to the changing thermal environment and how the different air parameters protect animals from heat stress. The most suggested and used approach is the one for Temperature Humidity Index (THI), expressing the relative significance of air temperature and humidity on heat stress among confined ruminants, pigs, and poultry.

Impact

Biophysical impacts on productivity are localized phenomena that are largely driven by local variations in weather impacts and mediated by local soil and water conditions[10]. Economic impacts, on the other hand, are embedded within complex phenomena including production, price, consumption, and trade responses to those local productivity impacts. However, the Montenegrin agricultural market is highly interconnected with regional markets, particularly bigger regional producers, such as Serbia and Croatia. Therefore, Montenegrin agricultural market is sensitive to biophysical impacts, behavioral responses among consumers and producers, and adaptation opportunities and constraints both within Montenegro and regionally. Moreover, globalization causes these interconnections to be even with the global agricultural market

Managing the impacts of climate change on Montenegrin agriculture is an interdisciplinary challenge that may be most effectively addressed using systems research strategies to integrate and develop disciplinary knowledge. For example, climate change can impact the livestock sector along a number of pathways: directly through impacts on productivity and

[10] https://www.academia.edu/8474562/Climate_change

performance and indirectly through price and availability of feed grains, competition for pastureland, and changing patterns and prevalence of pests and diseases. Therefore, it is highly connected to crop production impact, and the two sectors are strongly linked to fodder production.

The impact of environmental factors can be divided into 4 main groups **impact on soil**, including organic matter loss and erosion and reduced fertility, **impact on crops** including crop response to changes in agro-environment, yield reduction, new diseases, and pests; **Impact on livestock** including Reduced productivity and New diseases and pests, reduced animal welfare and **Impact on rural well-being** including reduced farm income, Increased cost of the production, Reduced economic power of the farms and Reduced interest for farming.

Table 4. Impact and indicators and their explanation

Impact	Expected response	Indicator
Soils		
Soil organic matter loss	Soil organic matter (as one of the most valuable soil components) is decomposed at a faster rate due to increased temperatures	Organic matter content in the soils to develop a baseline and regularly follow
Soil erosion	The erosion rate is increasing due to increased rainfall intensity and reduced organic matter and most fertile topsoil is reducing	Soil erosion was reported as: • Area affected • Soil removed
Reduction of soil fertility	Soil fertility is reduced due to losing the top layer, losing the organic matter and nutrients, and reduced microbiological activity	Soil nutrient content to develop a baseline and regularly follow
Crops		
Negative crop response to changes in agro-environment	Increased temperatures drive the crop growth faster, growth stages are shortened by time, decreased photosynthesis, less biomass accumulation, heat stress,	agrophenology — this indicator traces changes in the timing of the annual cycle of agricultural crops;

	water stress, pollination problems,	the growing season for agricultural crops — this indicator determines the suitability for growing agricultural crops, based on temperature regime;
Yield reduction	Lower biomass accumulation due to the negative crop response to increased temperature and changes in hydrological regime will cause less biomass partitioned in the storage organs and reduce the yield.	water-limited crop yield — this indicator considers potential changes in crop productivity caused by changes in temperature, rainfall, and atmospheric CO_2 concentration;
Crop quality reduction	The discoloration, sunburns, premature ripening, reduced protein content, etc. will reduce crop quality and decrease the market value of the crops	Protein content in cereal crops
New diseases and pests	New pests and diseases can further reduce yield potential due to the damages and low capacities of the farmers to recognize symptoms and to undertake measures	List of new pests and diseases
Livestock		
Reduced productivity	The animal response to disturbed comfort caused by the heat stress will reduce their fodder consumption and productivity	Productivity of livestock breeds
New diseases and pests	New pests and diseases can further reduce productivity potential. Moreover, if the disease is of high risk for the livestock system and human health the massive reduction	List of new pests and diseases

	of the livestock potential is possible.	
Reduced welfare	A hotter environment can reduce livestock welfare and cause uncomfortable feeling and losing of appetite. Combined with increased humidity in the livestock buildings can make animals feel exhausted and fatigued.	Thermal heat index
Rural well-being		
Reduced farm income	The lower yield, lower quality, and the lower market price will reduce farm income	Total farm income from FADN
The increased cost of the production	Increased need for fertilizers, more crop protection materials, increased water requirement, and need for investment in adaptation will increase production cost	Cost of production
Reduced economic power of the farms	Lower income and higher cost of production will reduce profitability and reduce the economic power of the farms, to the extent of non-profitable production	Investment in agriculture
Reduced interest in farming	Lower profitability from farm activities will further discourage farmers to keep doing their farming activities, the farmer's generation change will be even more difficult, and some farmers can abandon their farms and rural areas…	Number of the rural population Number of farms correlated with farm size

4.2. Risk metrics - criteria and indicators needed for the prioritization exercise

There is uncertainty associated with many of the steps necessary to assess the effects of climate change on agriculture. Some of that uncertainty arises because the science climate change is complex and continuously evolving. Other sources of uncertainty arise from an incomplete understanding of the effects of a multitude of climate variables and conditions on crop and livestock growth and development. The practice of anticipating human adaptation behavior in the future is inherently uncertain; observations of past behavior provide a good starting point, but advances in communication, information, and technology may fundamentally alter future conditions, and decision-making options, in ways that are not easy to predict. The lack of certainty about the expected effects of climate change complicates decision-making about how, and when, to develop adaptive strategies or invest in mitigating technologies. Nevertheless, decisions are made under uncertainty on a daily basis

Comprehensive risk management in the context of climate change would allow a subjective examination of the "risk-weighted" costs and benefits of launching various adaptation strategies, including potential investments in early-response systems, adaptation technologies, communication, and research infrastructure, capacity building, etc., given uncertainty about which climate and impact scenario will ultimately emerge. The approach requires the quantification of an enormous amount of information about potential climate outcomes, their probability of occurrence, and their effects, however. Few efforts have been made to develop such comprehensive quantification efforts in the context of climate change

The following table is presenting the major risks associated with the vulnerability of the agricultural sector to climate change:

Table 5. Risk criteria and baseline indicators

Type	Risk	Base
Exposure	**Temperature** increase	mean: 9.49°C; range 7,97 to 10,74; standard deviation 0,67 coefficient of variation 0,07.
	Annual rainfall decrease	1039,7 mm; range 499,1 to 1745,2; standard deviation 312,4 and coefficient of variation 0,30

	Drought - Aridity index by UNESCO	1,15; range 0,50 to 2,01; standard deviation 0,38 and coefficient of variation 0,18
	Extreme weather events	**TBD**
	Temperature Humidity Index (THI),	**TBD**
Sensitivity	**Irrigated land**	**Irrigated area in ha,** 7650-8670 ha
	Cultivated land	62 154 ha
	New diseases and pests in crops	List of diseases/pest /weeds and area affected in ha
	Number of livestock	Bovine 89 296; Sheep 191 992; Goat 31 458; Pigs 55 841; Poultry 835 705; Horses 3947.
	New diseases and pests in Livestock	List of diseases/pest and number of heads affected in ha
	The area under certain crops	Wheat 766,3 ha; Maize for grain 641,6 ha; Barley 394,9 ha; Oats 209,9 ha; Ray 181,7 ha; Potatoes 1616,0 ha; Alfalfa and clover and grass 1453,9 ha; Meadows 73252,2 ha; Orchards 12007 ha; Vineyards 4399 ha; 495200 fruit-bearing olive trees;
	Number of the rural population	TBD
	Soil organic matter in the topsoil	% Soil organic matter in the topsoil **TBD**
	Erosion risk	Modeled soil erosion (t/ha/year) **TBD**
Adaptation capacity	**Average farm size**	5,9 ha Utilized Agricultural Area for crops; 1,39 ha for grape; 0,29ha for orchards; 4 bovines; 35 sheep; 9 goats; 4 pigs; 45 poultry;
	Number of agricultural holdings	43 791
	The age structure of farmers	**TBD**
	Level of education of farmers	**TBD**
	Farm size by economic class	**TBD**

	Number of research papers in Scopus (or WoS) in agriculture	**TBD**

Indicators are divided into 3 groups: Exposure, Sensitivity, and Adaptation capacity. The choice of indicators was based on the data available, or in the case when data is not available, the choice was based on the data that the country should have according to the level of approximation to the EU. Therefore, the indicators for adaptation capacity indicates as TBD (To Be Defined) are an obligation that should be conducted from the agricultural census and Farm Structural Survey - FSS (according to the EUROSTAT the agricultural census should be conducted every 10 years, and between the two censuses 2-3 farm structure surveys should take place).

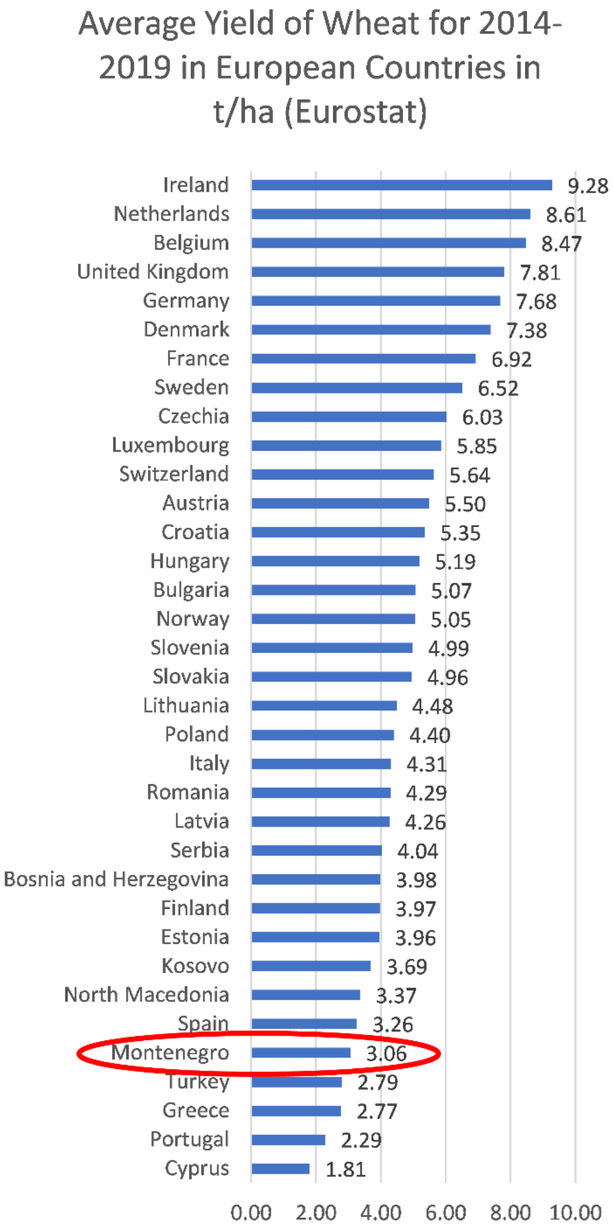
4.3. Identified vulnerability of the sector Agriculture

With respect to a managed system such as agriculture, vulnerability can be thought of as being comprised of three categories of factors that influence the overall potential for impacts, or vulnerability (IPCC 2015):

1) the climate itself;
2) biophysical factors that influence how climatic conditions are translating into impacts; and
3) human, or management, factors that further mediate how climate influences agriculture, and abilities to adapt to changing conditions, including climate change and extreme weather.

As the climate changes and hazardous climate events and conditions occur in greater frequency, intensity, and duration, the vulnerabilities in a given system can become more severe if sources of current vulnerability are not addressed. It is often recognized in climate change adaptation guidelines that vulnerabilities can be addressed by increasing the adaptive capacity of a given system.

Frequently the present yield data is used to understand the adaptive capacity of agriculture. Lower than average yield means a lack of capacities to cope with the present situation and therefore considered a lack of adaptive capacities for future climate change weather events. The yield of wheat (C3 crop) and maize (C4 crop) are compared with yields in other European countries in the following figures.



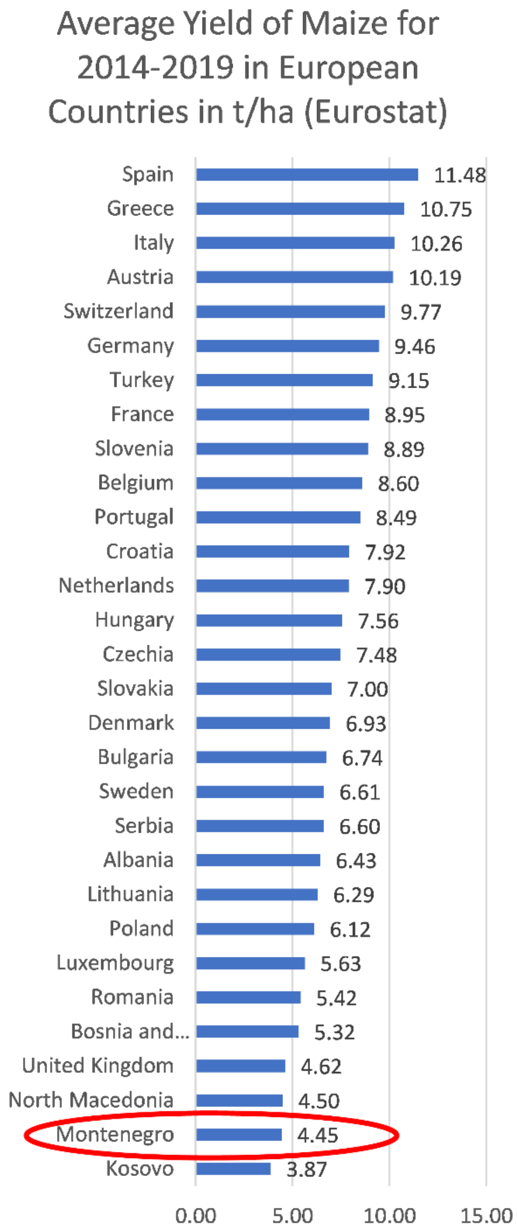


Figure 5 . Average yield of wheat and maize for European countries in t/ha for the period 2014-2019 (source: EUROSTAT)

The data presented in the figures clearly show that crop yields in Montenegro are far below the European average, and among the lowest in Europe, therefore it is a clear sign of a lack of adaptive capacities. Low adaptive capacities are always associated with high vulnerability, particularly in Southern parts of Europe and the Mediterranean area, well-known regions where climate change will have a negative impact on crop production.

Moreover, the very low yield compared to other countries in Europe (including the countries from the region) can be a sign that changing climate has already expressed its negative effects on Montenegrin agriculture and combined with low adaptive capacities created a situation where crop productivity is far below European (and regional) average.

The high temperature should be always analyzed in combination with water availability. Crops used a huge amount of water on transpiration not only for photosynthesis and transport of nutrients and assimilates, but also for cooling. The crops reacted differently to the high temperatures by changing the angle of the leaves, banding the leaves, making the spiral shape of the leaves, etc., just in order to reduce the portion of the leaves exposed to direct sunlight. Real cooling can be done only by evaporative cooling as a result of transpiration. However, the efficiency of this cooling is not very high, frequently there is not enough water and sometimes the transport of water from the roots to the leaves cannot be fast enough to transport a sufficient amount of water for transpiration. In such cases, crops will experience so-called physiological drought, or crops experienced drought even though there is a sufficient amount of water in the soil. The agricultural drought is happening almost every growing season, in some parts of the year or in some regions.

However, the crops are exposed not only to high temperatures, lower precipitation, and strong droughts. The opposite extremes as low temperatures and excessive rainfalls are also affecting crop production. The important question is the last frost that happened in spring. The frequent frost damage on the early flowering fruits is recorded in the historical records. If last spring frost will be later in the season the damages are higher, more crops are affected and the economic impact is alleviated. Moreover, the early autumn frost can damage crops with a late harvest.

The excessive rainfalls create water logging on low permeable soils. Some crops such as green pepper is very sensitive to waterlogging and lack of air in the soils and quickly reacts to such condition. The crop can be destroyed even with several consecutive days of water logging. Moreover, the floods are associated with intensive rainfalls, particularly flash floods. The intensive rainfalls are promoting erosion processes and a number of other problems associated with weather and extrema weather events are present in the country. These situations are evident even in the present climate and it is expected to grow. Low adaptive capacities will make the crop sector more vulnerable than previously.

The heating caused by climate change will cause higher than optimal maximal temperatures for photosynthetic activities during most of the growing season and crops will reduce their organic matter synthesis. The high temperatures expressed as prolonged and more severe heat waves will even increase present yield losses caused by heat waves and high temperatures. Moreover, the high temperatures contribute to the sun burns and discoloration of the fruits. The high temperatures combined with higher insolation are causing sunburns, on the crops, which is very evident on the terrains with West exposition or on the west side of the fields.

Among the first documents addressing the vulnerability of the agricultural sector is The Initial National Communication on Climate Change of Montenegro published in 2010. The Second National Communication was prepared in 2015 using the same climate scenarios and periods as the previous one. The Third National Communication, like the previous two, contains an extensive elaboration of the historical weather and hydrometeorological hazards important for agriculture (floods, droughts, and heat waves). The climate scenarios for future weather are very well elaborated and in line with the IPCC standards.

All of the above-mentioned National Communication to the UNFCCC include analyses of the sector agriculture. The conclusions of the national communications related to the vulnerability of the sector agriculture, as well as the observation of the experts in charged for the development of this assessment are grouped as it follows:

- Montenegro is provisionally divided into five production regions: Coastal Region, Zeta and Bjelopavlici Region, Karst Region, Polimlje-Ibar Region, and Northern-mountainous Region. The most important crops are grapes, vegetables, potatoes, and fruits, while cereals and industrial crops (sugar and oil crops) are almost not present in the cropping pattern. Moreover, the document emphasizes livestock as the most significant branch of agriculture, participating with more than 60% of the total value of agricultural production.
- Soils are vulnerable to climate change, due to the increased temperature, and increased rainfall intensity that accelerates soil erosion and soil organic matter losses. The best quality soils are located in the river valleys, karst fields, and plateaus. The relief of the Montenegrin terrain is characterized by steep slopes above 10^o (65% of the territory), while slopes between 5^o and 10^o account for 28%. Only 7% of the territory has slopes that are less than 5^o, thus enabling the intensive use of land resources in agriculture without any significant consequences regarding erosion. Around 300 torrential basins are seriously affected by erosion; the volume of transported deposits exceeds 2 million m^3 per year. Land degradation neutrality is pointed out as one of the important factors in reducing the soil's vulnerability to CC. The analysis of the soil temperature is significantly improved and shows that in the last period the soil temperature is rising faster than usual. Moreover, the phenological data presented prove that flowering (crop growth stages) is shift several days earlier compared to the base period 1961-1990.
- The growing season length is increasing, and for the near future shows an increase by 11 days in the mountains with higher altitude, 18 days in the lower regions, and only

by 3 days in the coastal region. However, due to the increased variability in climatic data, it is quite hard to recommend the effective use of the prolonged growing season due to the risk of early autumn and/or late spring frosts. The vulnerability assessment deals with the weather indices and emphasizes that despite the growing season being projected to be longer, frost damages are quite possible and earlier sowing is not an option due to the possible yield loss.

- Particular attention is given to the drought and Drought Management Center of Southeast Europe as a source of information and know-how in drought management. Moreover, drought is emphasized as the highest priority and main limiting factor of crop production. It is evident that Montenegro invested a lot of effort in drought assessment and the National Drought Plan of Montenegro recommends the Drought Watch platform for drought analysis. This clearly indicates that drought is considered one of the most important problems in the country and frequently and heavily affects agriculture and reduces productivity. The drought-vulnerable areas are Zeta River Valley, the Bjelopavlići Plain, and the coastal area (slight to moderate vulnerability). The West coastal area is emphasized as the most vulnerable area.
- The floods are causing severe damage to crop production and sometimes disturb soils that will be deposited by flooding material.
- The livestock is affected by reduced fodder availability due to drought and heat stress as a result of increased temperature and more frequent and longer heat waves and floods due to difficulties for livestock evacuation. Moreover, the increased temperature disturbs the environment in the barns and buildings livestock is accommodated, the heat stress became pronounced and reduces productivity.
- The increased temperatures change the thermal conditions and some regions get characteristics of the thermal regime of the south. The new environment creates favorable conditions for some pests and diseases to move from South to North. Therefore, new pests and diseases can create serious problems with agricultural production because farmers are not familiar with their symptoms, treatment, and management practices. Montenegro is also vulnerable to the following new pest and diseases which were determined in the recent period:
    - Tuta Absoluta - Tomato leafminer was detected for the first time in Montenegro using pheromone traps in the middle of July 2010, in greenhouses in one location on the Montenegrin sea coast (Hrnčić, S., & Radonjić, 2014)
    - Lumpy Skin Disease is an infectious disease in cattle caused by a virus of the family Poxviridae, also known as Neethling virus, it first appearance in 2016 in Gusinje, Montenegro stopped meat export due to this disease (www.vijesti.me)

- Bluetongue disease is a noncontagious, insect-borne, viral disease of ruminants, mainly sheep and less frequently cattle, first appearance in 2001 in region of Rozaje (Duric et al, 2004) with later outbreaks in 2014 and 2020.

In addition to the above and in line with the risk Metrix developed by the team of this assignment, the following direct and indirect effects of climate change on crop production are identified and presented in the table below this text.

Table 6. Direct and indirect effects of climate change on crop production

Climate change's direct and indirect effects on crop production	**Crop responses to direct climate change effects**	
Climate change impact	**Direct effect**	**Crop response**
Direct effects • **Increasing CO2 levels** • **Changes in temperature, rainfall,** • **radiation and humidity** • **Extreme events, e.g., heat waves, hail,** • **drought and flooding**	Increased CO_2	Increases in yield if other factors remain constant
	Increased temperature	Accelerates development and maturity resulting in yield reductions
	Decreased temperature	Increases susceptibility to late frosts
Indirect effects • **Shifts in crop suitability – creating a northward**	Decreased rainfall	Yield reductions (although can be offset by

expansion of warm-season crops • **Changes in plant nutrition and the increasing incidence of weeds, diseases, and pests' pressures** • **Degradation of resources, e.g., soil erosion; nutrient losses, and environmental pollution**		early development)
	Increasing rainfall	Increases lodging resulting in yield loss

Source: Rial-Lovera et al., 2016

As vulnerability is a product of the impact and adaptive capacities, and impact is a product of exposure and sensitivity the following vulnerability indicators are determined.

Table 7. Vulnerability indicators determined and their effects on vulnerability in agriculture

Type	Indicator	Effects on vulnerability
Exposure	**Temperature** increase	**Negative: Higher temperature accumulation, shortening of the growing period, less biomass production, moving the crop suitability to the north or to the higher elevation, heat stress**
	Annual rainfall decrease	**Negative: Water deficit for normal crop growth. Less water available for irrigation and for water supply in rural communities increased pressure on the water resources, possible conflicts for water**

	Drought - Aridity index by UNESCO	**Negative: Increased dryness will reduce crop productivity and water availability**
	Extreme weather events	**Negative: Damages on the crops, lower yield, and quality**
	Temperature Humidity Index (THI),	**Negative: Reduced productivity, reduced animal welfare**
Sensitivity	**Irrigated land**	**Positive: Irrigation will alleviate drought problems**
	Cultivated land	**Positive: higher cultivated land will increase total production, and economic power and can contribute to the modernization and intensification**
	New diseases and pests in crops	**Negative: yield reduction and higher cost of production**
	Number of livestock	**Positive: Increasing the number of livestock will increase total production and will contribute to the better nutrition of the population**
	New diseases and pests in Livestock	**Negative: reduction of productivity and higher cost of production**
	The area under certain crops	**Positive: increased area will increase production and will be a sign of higher interest in agricultural production**
	Number of the rural population	**Positive: people will remain in rural areas contributing to the rural development and increased agricultural production, productivity, and income diversification**

	Soil organic matter in the topsoil	**Negative: Losing of organic matter reduces soil fertility, and reduces productivity**
	Erosion risk	**Negative: Losing the topsoil will reduce soil fertility and suitability**
Adaptation capacity	**Average farm size**	**Positive: bigger farms are usually with higher economic potential, with better possibilities for investment, modernization, and profitability**
	Number of agricultural holdings	**Negative: more holdings, means more farm owners with questionable education and knowledge of modern agriculture, smaller farms, and therefore more vulnerable to CC**
	The age structure of farmers	**Negative: older farmers do not have readiness for changes**
	Level of education of farmers	**Positive: A higher level of education is contributing to the increased know-how and success rate of the new investments and increase in productivity**
	Farm size by economic class	**Positive: Higher the economic size farms are with higher capacity to cope with vulnerability and to apply adaptation measures**
	Number of research papers in Scopus (or WoS) in agriculture	**Positive: bigger number of the papers show that the knowledge base is increasing, higher investment in research, and better, research-based higher education**

However, the vulnerability can be reduced by the implementation of adaptation measures. Adaptation of agriculture is frequently considered less important than research in vulnerability due to the common approach that farmers will autonomously change their practices and adapt to the conditions prevailing. However, the farms in the country are very small by physical size, with low productivity and low capacities for adaptation. Therefore, the number of farms according to their size, economic power, and level of education cannot invest in new technologies, in innovations and cannot easily adapt to any new situation.

4.4. Climate-driven vulnerabilities and gender-disaggregated impacts of the sector agriculture

Agriculture is maybe the most complex vulnerable sector in the gender vulnerability in climate change context due to the fact that it intersects all above mentioned vulnerabilities in terms of: poverty structure, labor structure, ownership structure, decision-making processes, household categories, education, health climate change hazards, indoor pollution, food and nutrition, access to water (for home use and irrigation), climate change weather extremes, climate change and tourism development, etc.

In addition to the social factors, as a result from climate change rural households, rural and agricultural lands, agricultural holdings are facing increased risks from droughts, floods, soil degradation, as well unexpected changes in the growing season.

These negative impacts are increasingly noted in the small scale and subsistence farming in the low-income context that have to be targeted separately due to the fact that are mostly presented by women, and women who are self-employed in agriculture tend to have smaller holdings and lower productivity, lacking of access to the financial support, infrastructure, access to markets and other services which are boosting agricultural productivity.[11]

In the sector agriculture in general, women are most often **unpaid worke**rs on family farms and paid or unpaid workers on other farms and agricultural enterprises. They are often involved in growing crops and nurturing livestock for their own and commercial needs. They produce food and are often involved in mixed farming operations.

In purpose of identifying and defining the gender based vulnerable groups, a Multifactor analysis approach is needed due to the complexity and different nature of the factors which are defining the gender-based vulnerability (social, economic, climate, cultural).

The Gender profile in Montenegro in the context of water, tourism, agriculture and health there are significant differences between women and men that have to be considered in order to clearly and precisely define the gender-based vulnerabilities in each of the sectors.

In other words, gendered vulnerabilities are resulting from multiple interactions of social (in wide meaning of the term) and biophysical factors. In that regard following aspects have to be cross-referenced in defining the gendered vulnerability:

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[11] FAO, 2018: Guidance note on gender-sensitive vulnerability assessments in agriculture

1. Geographical (Central, Coastal and North if applicable, which means if regional data are available and if the vulnerability has regional characteristics)

2. Governance and institutional factor (adaptation measures with gender responsive dimension)

3. Household level (power relations, gender-based roles, control over resources, ownership)

4. Coping and adaptive capacity (socio-economic factors, decision making processes)

In Montenegro, the biggest share of the percentage of households that own Agricultural land is in the North Region with 52.4% followed by the 41.2% share in the Central Region[12]. North Region has also the biggest share in the households with Farm animals/Livestock, and at the same time is the region with the biggest representation of housewives in the inactive labor force with 21% of the total inactive rate, and is the region with the biggest gap in registered Rural households for the touristic purposes with 20% participation in the total number of registered rural households.

The educational structure of the labor force at the family agricultural farms shows that women`s share in the category “without education” is 100%. The share of women with 4 years of secondary school is 33.22% and 66.78% men, while the share in the higher or higher agricultural education 72.89% for men and women in 27.11%. Participation of persons with other senior or higher education is 74.37% among men and 25.63% for women[13].

Still, the **educational structure** shows even and higher participation of female population in the area of agriculture, food processing and food production in Montenegro, with 46,6%[14] women who completed secondary school in the area of agriculture, food processing and food

[12] Multiple Indicator Cluster Survey 2018, Montenegro and Montenegro Roma Settlements, available at https://www.unicef.org/montenegro/media/15976/file/mne-media-publication1002.pdf Table SR.2.2., page 67

[13] MONSTAT: Agricultural census, 2010 available at: https://www.monstat.org/userfiles/file/popis%20poljoprivrede/VI%20knjiga%20CG%20v3.pdf

[14] MONSTAT, Women and men in Montenegro 2020, https://www.monstat.org/uploads/files/publikacije/%C5%BDene%20i%20mu%C5%A1karci%20u%20Crnoj%20Gori.pdf

production, 62%[15] women among graduate students (basic studies) in Agriculture, and 75% doctors[16] in the field of Agriculture, Forestry, Fisheries and veterinary.

The female dominance in the educational structure in the agriculture sector is unfortunately not reflected in the labor market and management (ownership) structure as well.

Women are holders of **12,87% of** family farms[17], **32,2% are** employed in Agriculture, Forestry and Fishery[18]**. 42,3%,** of women work in agricultural holdings[19], **35,2%** work in agricultural production[20] **and 36,1%** women are representing the skilled agricultural workers**[21].**

This is amended with the data that 94,2% of the business entities in the category Agriculture, forestry and fishing are owned by men[22]. On the other hand, 91,4% is the men`s share in the category: Agricultural production, hunting and related service activities[23], whilst the **ownership status in agriculture** is dominated by men which in 87% are holders of family agricultural holdings, in 60% are agricultural workers, in 94% are managers of business entities[24]. On the other hand, 65% of women are unpaid family workers has to be also evidenced in the gender differences of the burden of labour.

This is tightly correlated to the decision-making processes at family level for adaptation practices on one hand, on the other, women traditionally do not inherit the property / agricultural area which leads to their inability to manage and access supporting financing instruments.

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[15] Ibid, page 170

[16] Data obtained in May 2022 for the purpose of the analysis for Gender Action Plan and Gender Communication Plan with Gender Mainstreaming Features in the Design and Implementation of the NAP in Montenegro

[17] MONSTAT Women and Men in Montenegro 2020, https://www.monstat.org/uploads/files/publikacije/%C5%BDene%20i%20mu%C5%A1karci%20u%20Crnoj%20Gori.pdf

[18] MONSTAT Statistical yearbook of Montenegro 2021, page 57

[19] MONSTAT, Struktura poljoprivrednih gazdinstava, 2016, https://monstat.org/userfiles/file/fss/Saopstenje%20FSS.pdf

[20] MONSTAT Statistical yearbook of Montenegro 2021, page 57

[21] MONSTAT, Women and men in Montenegro 2020, https://www.monstat.org/uploads/files/publikacije/%C5%BDene%20i%20mu%C5%A1karci%20u%20Crnoj%20Gori.pdf

[22] Analiza nosioci vlasnistva

[23] Ibid.

[24] AGRICULTURAL HOLDINGS IN MONTENEGRO – STRUCTURE, https://www.monstat.org/userfiles/file/popis%20poljoprivrede/VI%20knjiga%20%20ENG%20v3.pdf

In this case men have to be strongly involved in the consultation processes for adaptation practices, while women are defined as vulnerable groups due to their involvement in the decision-making and consultative processes. Their need in the agricultural work is neglected.

Women`s labor force in the agriculture holdings notices the biggest share of the age group 65+ for 2016 in 23.6%, followed by the age group 55-64 with 21%[25] out of the total number of women workers in the agricultural holdings.

The structure is the same among the male population, with 23% of workers from the age group 65+, and 22% of the age group 55-64 in the total number of male workers in the agricultural holdings[26]. **In other words, the population in the age groups 55-64 and 65+ are the most represented in the labor force in the agricultural holdings in Montenegro, which requires separate attention by the climate change-related actions, due to the fact that these groups are identified as vulnerable in terms of health and climate change hazards.**

Climate change and its adverse effects affect access to drinking water and irrigation water on agricultural land. This is directly related to female labor in the family - hygiene, home cooking or irrigation for the cultivation of certain types of crops - mostly near the home.

Therefore, following aspectsare strongly defining the defining gender vulnerability in the agriculture sector:

- In the agricultural sector, women generally have less control over land and livestock (ownership), much less use improved seeds, quality fertilizers and banking services such as credits and loans, which means they have a smaller share in the use of extension services/measures.
- Caring for dependent family members prevents women from being more present in the labor market, but the infrastructural (in)accessibility and remoteness of social, health, and educational services make their work at home even more difficult since it takes a lot of time to reach these services
- Women have traditionally been the guardians of cultural heritage and knowledge on the use of natural resources in health treatment/healing, cooking, etc.
- They are increasingly involved in vegetable production but are also involved in the production of dairy products, i.e. processing of dairy products, fruits, and vegetables
- They are less represented in natural resource utilization activities such as forestry, hunting, fishing

[25] MONSTAT: https://monstat.org/cg/page.php?id=1005&pageid=1005

[26] Ibid.

- Women are less represented in decision-making processes at the local level (and less informed about local policies).
- The educational structure and access to education for rural women is an important factor in strengthening the role of women in agriculture
- Women have less access to information on new technologies in both mitigation and adaptation.

Gender differences in agriculture can be clearly seen if we analyze the available gender statistics in the context of FAOs DOMAINS OF EMPOWERMENT[27] in agriculture:

Table 8 Gender statistics in the context of FAOs Domains of empowerment in agriculture

Domain of empowerment	Montenegro indicators	Men	Women
Resources: Ownership, access to, and decision-making power over productive resources such as land, livestock, agricultural equipment, consumer durables, and credit[28]	Holders of individual agricultural holdings[29]	87%	13%
	Managers of business entities[30]	94%	6%
Income: Sole or joint control over income and expenditures	Holders of individual agricultural holdings[31]	87%	13%
	Managers of business entities[32]	94%	6%
Leadership: Membership in economic or social groups and comfort in speaking in public	/	/	/

[27] A woman is defined as empowered in 5DE if she has adequate achievements in four of the five domains or is empowered in some combination of the weighted indicators that reflect 80 percent total adequacy.

[28] https://weai.ifpri.info/about-weai/

[29] Analiza nosioci vlasnistva table 3, Monstat 2011, p.8

[30] Analiza nosioci vlasnistva table 3, Monstat 2011, p.8

[31] Analiza nosioci vlasnistva table 3, Monstat 2011, p.8

[32] Analiza nosioci vlasnistva table 3, Monstat 2011, p.8

Time: Allocation of time to productive and domestic tasks and satisfaction with the available time for leisure activities[33]	Unpaid family workers	35%	65%

It can be concluded that in the 4 areas of empowerment which are production, resources, income (leadership as well due to higher rate of men in the ownership and land control), men are highly dominating, while women are dominating in the (un) empowering factor which is the unpaid labor.

In terms of gender vulnerabilities in agriculture, the possible vulnerable groups are as following:

Unpaid family workers – women in general, and in terms of access to the communication strategies, decision making, and financial instruments. The female workforce at the family agricultural farms is also defined as vulnerable due to the lower educational level.

Holders and managers of individual agricultural holdings: men in terms of practicing adaptation practices, women in terms of access to the communication strategies, decision making and financial instruments.

North region is identified as the most vulnerable in terms of women`s participation in the unpaid labour and smallest share of owners of rural households for touristic purposes (at the same time) with 52.4% followed by the 41.2% share in the central region[34].

Access to water in rural areas and Roma settlements is identified as the most vulnerable, where the burden of female unpaid labor is biggest (indoor activities and irrigation and related to the cultivation of crops – mostly near the home, and nurturing livestock for their own and small sale commercial needs)

Data from the agricultural sector are indicating that men can be more affected by **droughts** due to the fat that in 87% they are holders of individual agricultural holdings, in 60% are agricultural workers, in 94% are managers of business entities. Still, the fact that 65% of

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33 https://www.bing.com/ck/a?!&&p=8620a6e7d46f44abJmltdHM9MTY3MDgwMzIwMCZpZ3VpZD0wMWRkZGVjYy1lOTA1LTY2ZjQtMWNiYy1jY2I0ZTgxNzY3MTgmaW5zaWQ9NTEyOA&ptn=3&hsh=3&fclid=01dddecc-e905-66f4-1cbc-ccb4e8176718&u=a1aHR0cHM6Ly93d3cub3BoaS5vcmcudWsvd3AtY29udGVudC91cGxvYWRzLzIwMTJfV0VBSV9Ccm9jaHVyZS5wZGY&ntb=1

34 Multiple Indicator Cluster Survey 2018, Montenegro and Montenegro Roma Settlements, available at https://www.unicef.org/montenegro/media/15976/file/mne-media-publication1002.pdf Table SR.2.2., page 67

women are unpaid family workers has to be also evidenced in the gender differences of the burden of labour in the cases of droughts.

The table below provides an overview of the most prioritized vulnerabilities of the sector agriculture and their gender disaggregated impact.

Sectoral vulnerability	Geographical area (where applicable)			Household level Gender-based roles	Gender differences in exposure and hazards	Gender differences in the Coping and adaptive capacity	GENDER DISAGGREGATED IMPACTS[35]
	North	Costal	Central				
Agriculture	Moderate	High	High	Moderate	Moderate	High	Ownership status in agriculture is dominated by men which in 87% are holders of individual agricultural holdings, 60% are agricultural workers, 94% are managers of business entities. 65% of women are unpaid family workers has to be also evidenced in the gender differences of the burden of labour **Women`s labor force in the agriculture holdings notices the biggest share of the age group 65+ for 2016 in 23.6%, followed by the age group 55-64 with 21%** **male population, with 23% of workers from the age group 65+, and 22% of the age group 55-64**
Vulnerability 1Yield reduction - Lower biomass accumulation due to the negative crop response to increased temperature and changes in hydrological regime will cause less biomass	Moderate	High	High	Moderate	Moderate	High	

partitioned in the storage organs and reduce the yield							
Vulnerability 2 Crop quality reduction - The discoloration, sunburns, premature ripening, reduced protein content, etc. will reduce crop quality and decrease the market value of the crops	Moderate	High	High	Moderate	Moderate	High	
Vulnerability 3 Reduced productivity of the livestock - The animal response to disturbed comfort caused by the heat stress will reduce their fodder consumption and productivity	High	High	High	Moderate	Moderate	Moderate	
Economic damage due to reduced grain production	Moderate	Low	Moderate	Moderate High	Moderate High	Moderate High	ownership status in agriculture is dominated by men which in 87% are holders of individual agricultural holdings, 60% are agricultural workers, 94% are managers of business entities.

[35] The Multi Criteria Analisis is populated by the RVA and was based on expert judgment, literature review, and exchange with the relevant stakeholders

							65% of women are unpaid family workers has to be also evidenced in the gender differences of the burden of labour
Economic damage due to the consumption of additional quantities of water and electricity for irrigation	Moderate	Low	Moderate	Moderate High	Moderate High	Moderate High	ownership status in agriculture is dominated by men which in 87% are holders of individual agricultural holdings, 60% are agricultural workers, 94% are managers of business entities. 65% of women are unpaid family workers has to be also evidenced in the gender differences of the burden of labour **- % of women cooking and/or doing housework, every day (18+ population) is in 68% and male`s share is 10.3 %.** **Access to water: rural areas and Roma - most vulnerable, - female unpaid labor is biggest (indoor activities and irrigation and related to the cultivation of crops – mostly near the home, and nurturing livestock for their own and small sale commercial needs)**
Economic damage due to reduced production of other crops	Moderate	Low	Moderate	Not known	Not known	Not known	**No sex-disaggregated data for Montenegro**

5. Future risks to sector Agriculture from climate change

5.1. Impact modeling

Crops

The effects of climate change on crop yield can be converted into the yield response using the crop model. There is a number of crop models in use, most of them are heavily data intensive and required a number of data that are not available in the country. Therefore, for the country best option are some less complex crop models that can be much easier transferred and need fewer intensive data sets. Moreover, the models of choice should be enough robust, the process of calibration and validation should be clear and datasets for this purpose should be available. The previous research in crop yield response to climate change emphasized the water limitation as a major driver for yield reduction in the present and even more in future climate. Therefore, the choice of the model is using the FAO AquaCrop model, which is heavily supported by a number of researchers and institutions and globally recognized as a robust model that can operate with reduced data inputs. It was particularly important because the data required for modeling, validation, and calibration in the country is lacking, or if existing, access to the data is heavily restricted.

AquaCrop is a crop growth model developed by the Land and Water Division of FAO to address food security and to assess the effect of environment and management on crop production[36]. AquaCrop simulates yield response to water of herbaceous crops and is particularly suited to address conditions where water is a key limiting factor in crop production[37]. When designing the model, an optimum balance between simplicity, accuracy, and robustness was pursued. To be widely applicable AquaCrop uses only a relatively small number of explicit parameters and mostly intuitive input variables requiring simple methods for their determination[38]. On the other hand, the calculation procedures are grounded on basic and often complex biophysical processes to guarantee an accurate simulation of the response of the crop in the plant-soil system.

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[36] https://www.fao.org/aquacrop/overview/whatisaquacrop/en//

[37] https://www.researchgate.net/publication/262030395_Using_AQUACROP_to_model_the_impacts_of_future_climates_on_crop_production_and_possible_adaptation_strategies_in_Sardinia_and_Tunisia

[38] https://www.fao.org/aquacrop/overview/whatisaquacrop/en/

The climate datasets used in the modeling process were sourced from the EURO-CORDEX data portal, post-processed, and converted into the format suitable for use with the AquaCrop model by the Agricultural Expert from the team which is in same time working for the Department of Irrigation of Agricultural crops at Ss, Cyril and Methodius University in Skopje. The reference period is set as period 1971-2010. The future climate is set for the near future from 2011 to 2040. The midterm period is set from 2041 to 2070. The GHG emissions scenario is RCP8.5 Representative Concentration Pathway 8.5, which corresponds to the concentration of carbon that delivers global warming at an average of 8.5 watts per square meter across the planet. The RCP 8.5 pathway delivers a temperature increase of about 4.3˚C by 2100, relative to pre-industrial temperatures. The future climate projections of essential climate variables, temperature, and precipitation, as well as evapotranspiration for the territory of Montenegro. The datasets were downloaded from the

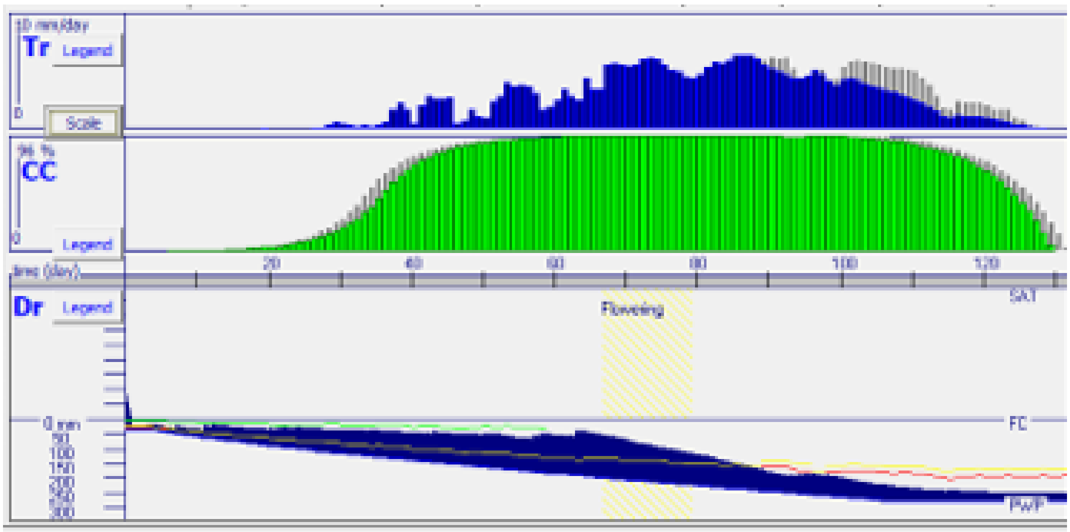
The AquaCrop model considers the number of parameters that can be set in order to conduct the modeling for various environments. The modeling was done using the daily values for the 4 basic meteorological parameters (maximal daily temperature, minimal daily temperature, daily rainfall accumulation, and daily evapotranspiration).

The crop modeled was maize, as a crop that is very tolerant to the increased temperature (crop with C4 photosynthesis pathway) and has a very positive response to irrigation. The maize simulates the behavior of all C4 crops. The maize crop is usually irrigated and the data required for parametrization, calibration and validation of the model may be available from the national scientific community. The AquaCrop model does not work with perennial crops, therefor the orchards and vineyards cannot be modeled. Moreover, the data for wheat response to irrigation is very limited, wheat is rarely irrigated and almost no research in the country addresses irrigated wheat. Therefore, at this stage the crop model results will address only maize .

The modeling approach was to keep as much as possible of FAO calibrated and validated parameters. Therefore, the soil type used for modeling was deep and uniform sandy loam soil, without restriction in the fertility and rooting depth. The initial condition for the summer crops is that the topsoil layer is already dried, but the layers below the top layer are wet and water for germination and initial crop development is available.

The modeling results presented in the following figure show the two cases: i) good year, when water deficit starts after the flowering stage, canopy cower developed normally, ripening stage is less sensitive to the water shortage, and evident reduction in transpiration after the day of season 100 did not affect the yield and ii) water deficit took place before flowering, the crop is severely damaged by the water shortage and senescence took place before day 100. The yield is severely reduced and harvest is not possible.

i.



ii.

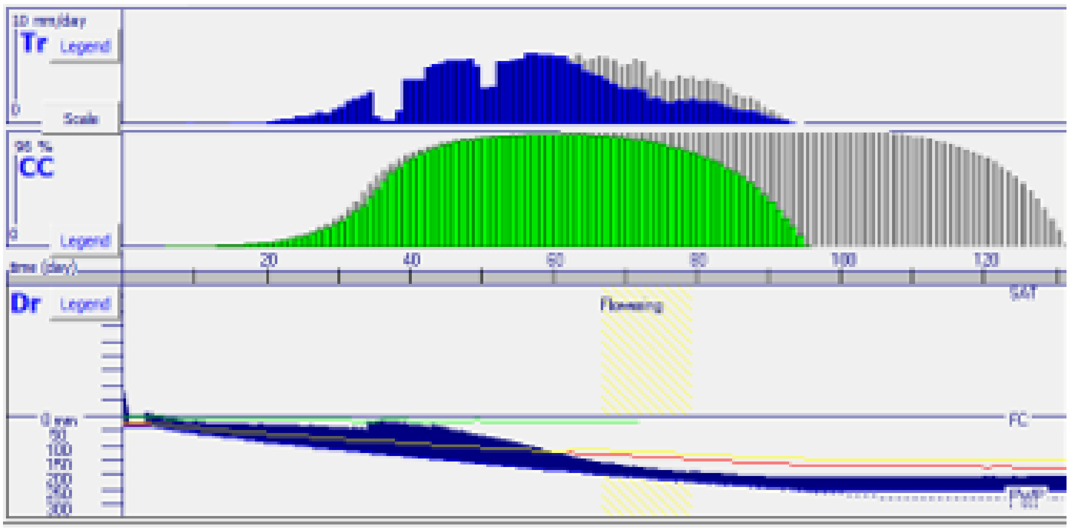


Figure 7 AquaCrop model output for the water deficit in different stages of the crop growth i) late stages and ii) early stages, and maize response to water deficit in different growth stages (Tr – transpiration, CC – Canopy cover, Dr- Root zone water depletion)

The figure above shows that the crop response to the water is not associated only with the amount of water but also with the period of crop growth when the deficit starts. However, the results for the vulnerability show that the maize crop is rather tolerant to the drought that will appear after the flowering stage. Particularly it is tolerant of water stress that appears after the milky ripening stage.

The maize yield resulting from modeling activities is presented on the following maps.

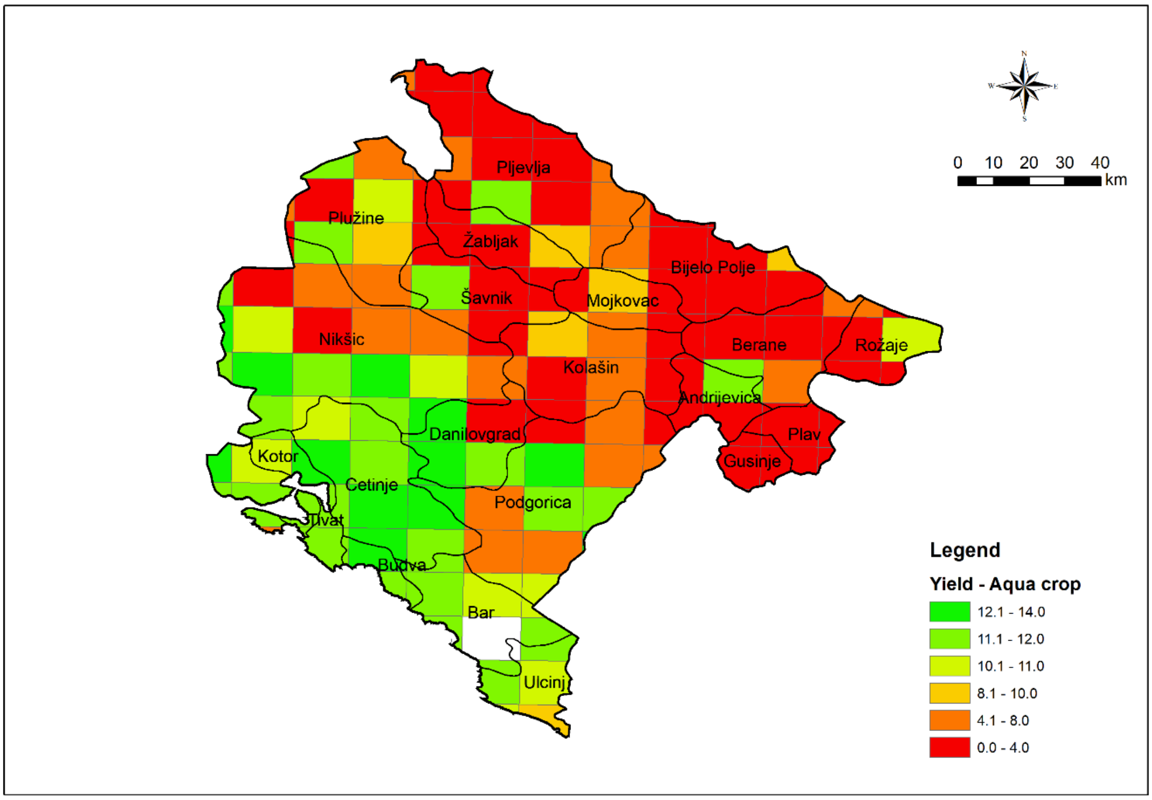


Figure 6 Maize Yield modeled by FAO AquaCrop period 1971-2000 (Base Case) in t/ha

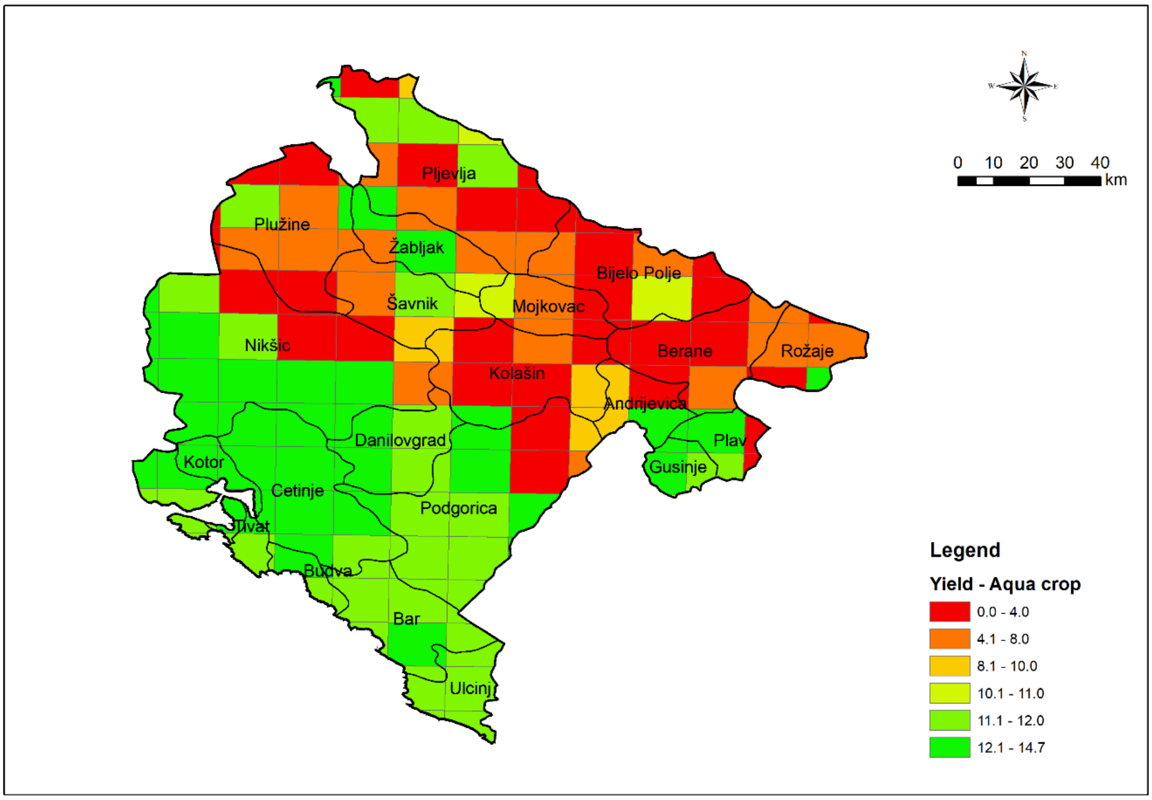


Figure 7 Maize Yield modeled by FAO AquaCrop period 2011-2040 and RCP 8.5 (Near Future Case) in t/ha

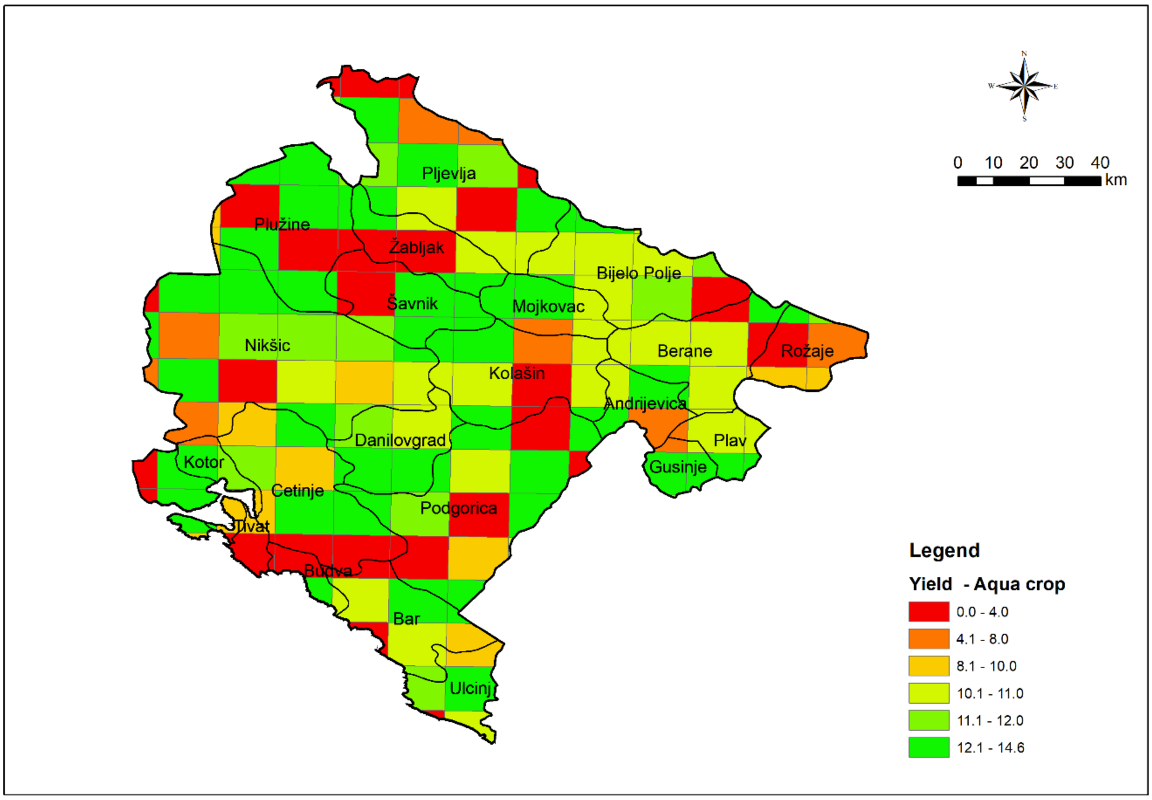


Figure 8 Maize Yield modeled by FAO AquaCrop period 2041-2070 and RCP 8.5 (Mid Future Case) in t/ha

As it can be seen on the Figures above, the maize response to climate change in Montenegro is diverse. The present weather, particularly temperatures limiting maize productivity in the North (higher elevated region) and the most productive zones are associated with the South part of Niksic and Danilovgrad municipalities, municipalities of Kotor, Tivat, Budva, Bar, Ulcinj, and Cetinje, and central part of Podgorica municipality. However, most of the coastal municipalities are preoccupied with touristic activities and maize is not the first crop of choice, because the climate allows for growing much more profitable crops such as vegetables, olives, and fruits that are far more marketable, particularly during the touristic season.

The maize productivity (C4 crop) for the near future is going to be even better and the crop will be more productive almost over the whole territory of the country. The most productive zone is moving to the north, and despite coastal municipalities include almost the whole territory of Niksic, Danilovgrad and Podgorica municipalities. Due to the temperature rise, there is a very positive effect in the Northern regions, and some higher elevated areas are becoming more productive and suitable for maize growing, previously restricted by thermal conditions. The North -East municipalities Plav, Gusinje and Andrijevica, as well as parts of

Zabljak, Plevlja, Gusinje, and Savnik are characterized by better suitability for maize growing and potential for achieving higher yield in near future.

The mid future situation is characterized by the spreading of the maize growing suitability almost over the whole country. However, the southern part of the country is going to reduce productivity potential even for maize which is one of the most heat tolerant crops with very efficient water use. Parts of Tivat, Cetinje, Budva, Bar, and Niksic municipalities are going to reduce yielding potential below the rentability threshold. However, this worsening of the situation in the South can be compensated by the much better yielding potential in the north of the country. Therefore, North Niksic, Shavnik, Pluzane, Mojkovac, Plevlja, and the Nort east municipalities Berane, Plav, and Gusinje can offer conditions for compensating severe productivity decrease in the southern part.

Clearly one of the important impacts of climate change is that model confirmed the shift of suitable zone for C3 crops to the north of the country, and to the higher elevated areas.

Yield changes due to climate change

The important analysis of climate change is the yield response to the changing climate. The yield modeling was conducted for the baseline period 1971-2000 and the yield modeled for the period was used as a base case and compared to the two periods in the future (near future 2011-2040 and mid-future 2041-2070. The results presented below are relative differences in yield obtained during the modeling, using the FAO Aquacrop model.

A total of 5 crops were modeled to assess the effects of climate change on crop production in Montenegro.

Maize is representative of the crops with a C4 photosynthesis pathway that is by far more tolerant to the increased temperature and increased water deficit than winter wheat, which represents crops with a C3 photosynthesis pathway. The response of these cereal crops to climate change can be used as an indication for most of the C4 and C3 crops. Moreover, C4 crops are a very good alternative for the C3 crops in future conditions. Maize is planted on 632 ha and the average yield is 4,25t/ha for the period 2015-2020. The winter wheat for the same period is planted on 764 ha and the average yield is 3.05 t/ha. Even though these crops are probably not very important for the agricultural sector in the country they are a very good indication of the crop yield response to climate change for a number of other crops that are similar to these crops.

Three additional crops considered important in Montenegro's agricultural sector were implemented in modeling activities. The first one is the potato which is widely grown on arable land (1707 ha in 2020) and in the kitchen gardens (547 ha in 2020) which is about 2250 ha in the year 2020 (State statistical office). The second one is tomato, the crop that is selected as representative of the high-yielding vegetable crops. Moreover, tomato is a crop that requires intensive cultural practices, and usually cannot be grown without irrigation. The tomato for the period 2015-2020 is planted on 138 ha and the average yield is 33 t/ha. The last crop is the grape which is probably the most important crop in Montenegro, considering the area and economic impact in the sector. Moreover, traditionally a number of households grow their own small plots with grapes for family use. The Monstat present data for grapes on plantations and the average area for the period 2015-2020 is 2837 ha and the average yield is 8.47 t/ha.

All crops modeled are C3 crops (only maize is C4). These crops easily stop photosynthetic [39]activity when the temperature rises, particularly above 30°C, due to biochemical processes.

The modeling activities were conducted using the AquaCrop model and standard set of FAO validated parameters. However, the same parameters were used for all 3 modeled periods in order to see the effects of climate. The model covers all territory of the country because crop masks for Montenegro are not available, therefore the exact distribution of certain crop fields cannot be located and presented on the maps. Moreover, the irrigated areas cannot be spatially distributed over the country's territory, therefore two model runs are implemented. The first run was for not irrigated potatoes and the second run was for irrigated potatoes. The results in absolute values of the yield were converted in relative numbers that present yield

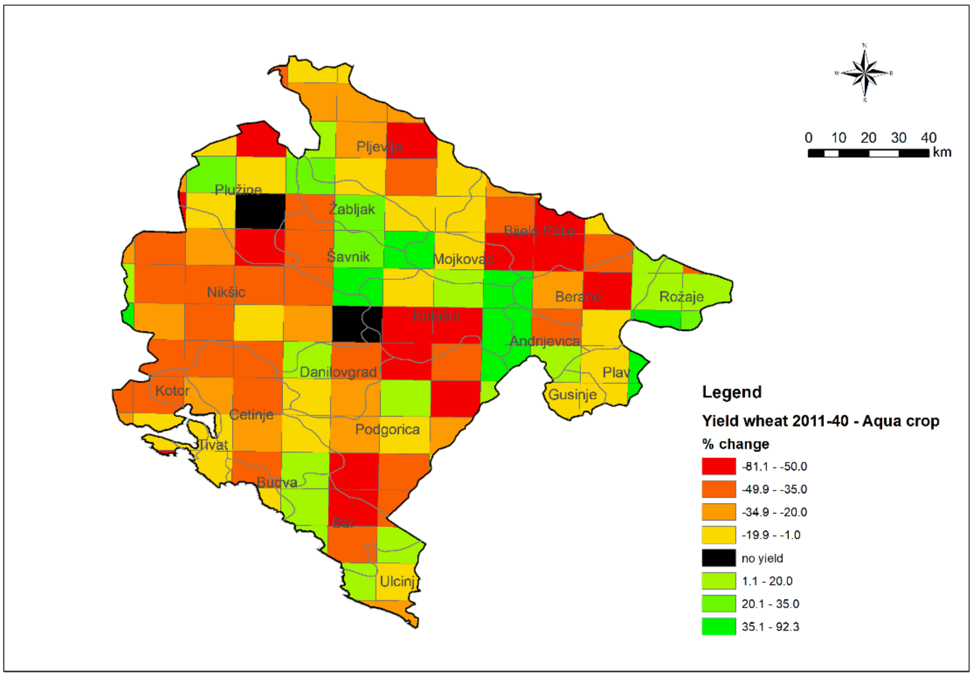
[39] Photosynthesis is the process that plants use to turn light, carbon dioxide, and water into sugars that fuel plant growth, using the primary photosynthetic enzyme Rubisco. The majority of plant species on Earth use C3 photosynthesis, in which the first carbon compound produced contains three carbon atoms. In this process, carbon dioxide enters a plant through its stomata (microscopic pores on plant leaves), where amidst a series of complex reactions, the enzyme Rubisco fixes carbon into sugar through the Calvin-Benson cycle. Although Rubisco aims to fix carbon dioxide, it can also fix oxygen molecules, which creates a toxic two-carbon compound. Rubisco fixes oxygen about 20 percent of the time, initiating a process called photorespiration that recycles the toxic compound. Photorespiration costs the plant energy it could have used to photosynthesize. Moreover, when stomata are open to let carbon dioxide in, they also let water vapor out, leaving C3 plants at a disadvantage in drought and high-temperature environments. However, plants have evolved another form of photosynthesis to help reduce these losses in hot, dry environments. In C4 photosynthesis, where a four-carbon compound is produced, unique leaf anatomy allows carbon dioxide to concentrate in the cells around Rubisco. This structure delivers carbon dioxide straight to Rubisco, effectively removing its contact with oxygen and the need for photorespiration. What's more, this adaptation allows plants to retain water through the ability to continue fixing carbon while stomata are closed. The maize and sorghum are C4 crops grown in the Southern Europe.

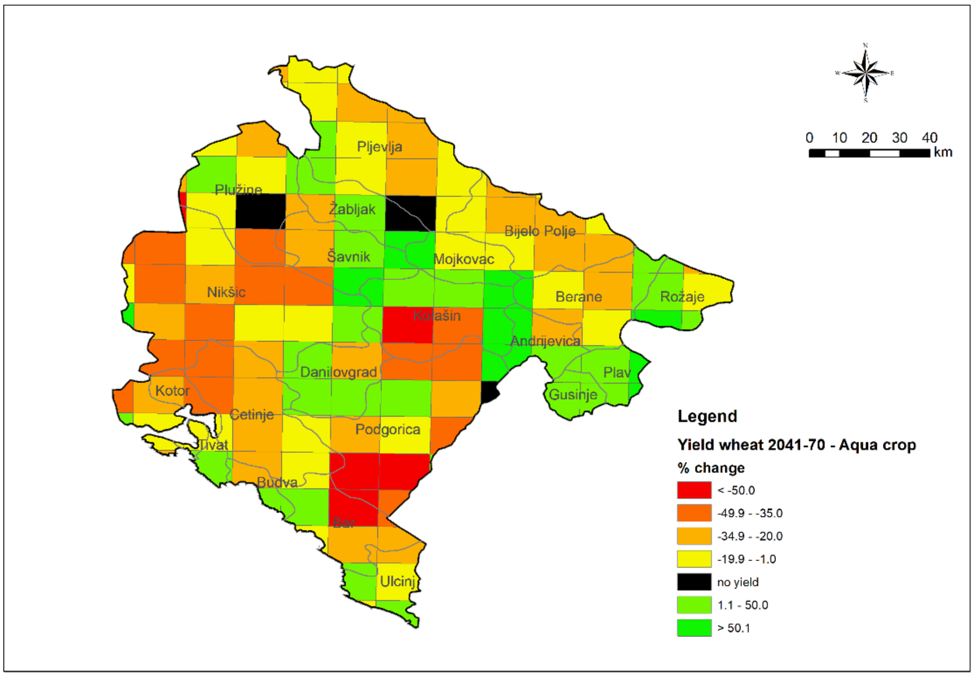
anomaly for two future periods (2011-2040 and 2041 to 2070) compared to the baseline period (1980-2010). The maps show yield change from the baseline situation in %.

Winter wheat

The winter wheat is a typical representative of the crops with a C3 photosynthetic pathway. The winter wheat yield anomaly due to climate change is presented in the following pictures.

A

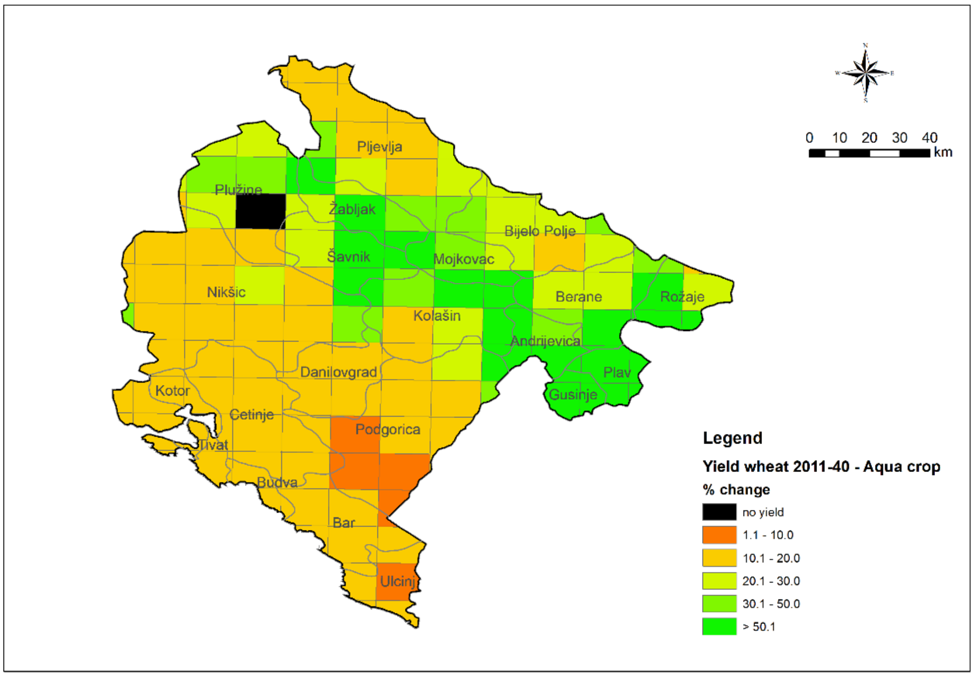


B	
	Figure 9 The average changes of the non-irrigated winter wheat yield as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

The non-irrigated winter wheat response to climate change for the period 2011-2040 is quite high and the expected highest yield reductions from 50-80% are modeled for some parts of the municipalities of Podgorica, Bar, Plevlja, Bijelo Polje , Berane, Kolasin and Plužine. The zones with the highest elevation in the model result express capacities for increasing the yield from 20 to 90%. However, this is not important for agricultural production because there is no agricultural land for planting cereals. Nevertheless, it can be quite important for livestock production because the mountain pastures located in this area, will increase biomass productivity and provide more fodder for the grazing livestock. A similar trend will remain for the period 2041-2070, but the maximal increase and decrease of the yield will be in the range of +50 to -50 percent. Also, the productivity of the high-level areas will spread compared to the previous period because of the increased temperature, higher CO_2 concentration, and better conditions for increased biomass productivity.

Winter wheat is typically not irrigated crop but have a very positive response to irrigation and can even double the productivity in irrigated condition. The results of modeling the irrigated winter wheat yield are presented on the figures below.

A



B

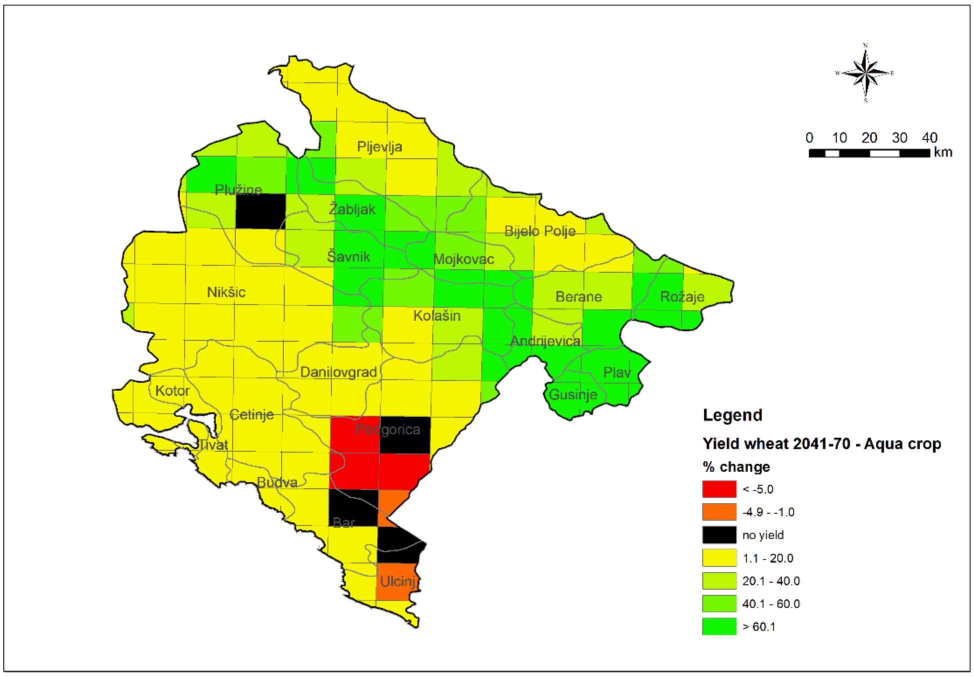


Figure 10. The average changes of the irrigated winter wheat yield as a result of climate change, the base period 1971-2000 compared to A. near future period 211-2040 and B. future period 2041-2070

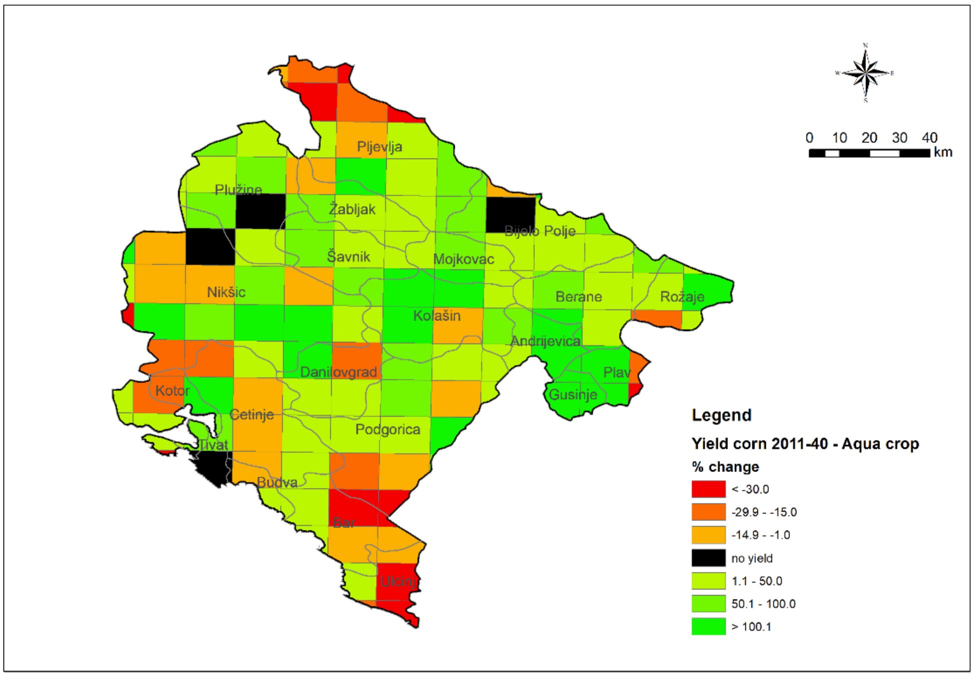
The irrigated winter wheat in the period 2011-2040 shows an increase in the yield all over the territory of Montenegro. The high elevated areas will experience an increase in the yield of more than 50%. The smallest increase by up to 10% is expected in the area of the south part of Podgorica municipality and in Ulcinj municipality. The reason for this is the irrigation scenario applied in the model that cannot provide a sufficient amount of water or high increase of temperature that makes C3 crop reduce photosynthetic potential. The rest of the country will experience a yield increase of 10 -30%.

The further increase of the temperature and CO_2 concentration in the period 2041-2070 will further disturb the productivity in the south Podgorica and Ulcinj municipalities and a yield decrease higher than 5% can be expected. However, the rest of the country will experience a slightly higher increase in wheat yield than in the previous period. Therefore, the irrigated winter wheat will increase productivity due to CO_2 fertilization and reduced water deficit. However, this can be accompanied by some negative effects, particularly lower protein content in the crops and reduced nutritional values. The CO2 fertilization is disturbing the C : N (carbon to nitrogen ratio) ratio in the crop and a higher concentration of C compounds reduces N compounds content, therefore there will be more starch and fewer proteins in the cereal crops.

Maize

Maize is a C4 crop and the expected response to climate change should be different than the winter wheat response. The maize crop is planted on 632 ha and the average yield is 4,25 t/ha for the period 2015-2020 (MONSTAT).

A


0 10 20 30 40
km
Pljevlja
Plužine
Žabljak
Bijelo Polje
Šavnik
Mojkovac
Nikšic
Berane
Rožaje
Kolašin
Andrijevica
Danilovgrad
Plav
Kotor
Gusinje
Cetinje
Podgorica
Tivat
Budva
Bar
Ulcinj
Legend
Yield corn 2011-40 - Aqua crop
% change
< -30.0
-29.9 - -15.0
-14.9 - -1.0
no yield
1.1 - 50.0
50.1 - 100.0
> 100.1

B

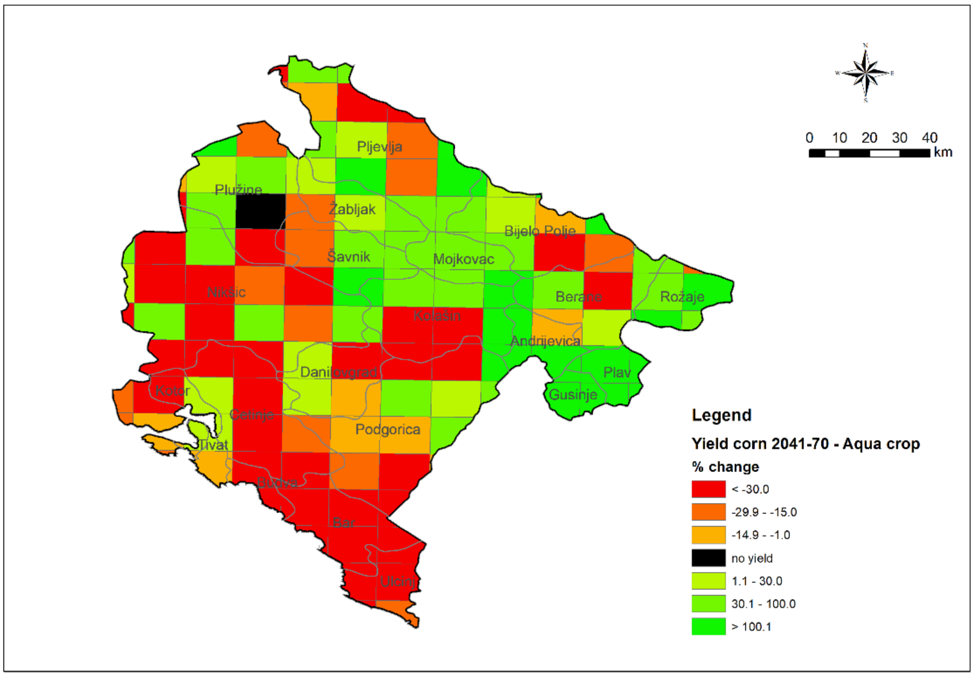

0 10 20 30 40
km
Pljevlja
Plužine
Žabljak
Bijelo Polje
Šavnik
Mojkovac
Nikšic
Berane
Rožaje
Kolašin
Andrijevica
Danilovgrad
Plav
Kotor
Gusinje
Cetinje
Podgorica
Tivat
Budva
Bar
Ulcinj
Legend
Yield corn 2041-70 - Aqua crop
% change
< -30.0
-29.9 - -15.0
-14.9 - -1.0
no yield
1.1 - 30.0
30.1 - 100.0
> 100.1

Figure 11. The average changes of the non-irrigated maize yield as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

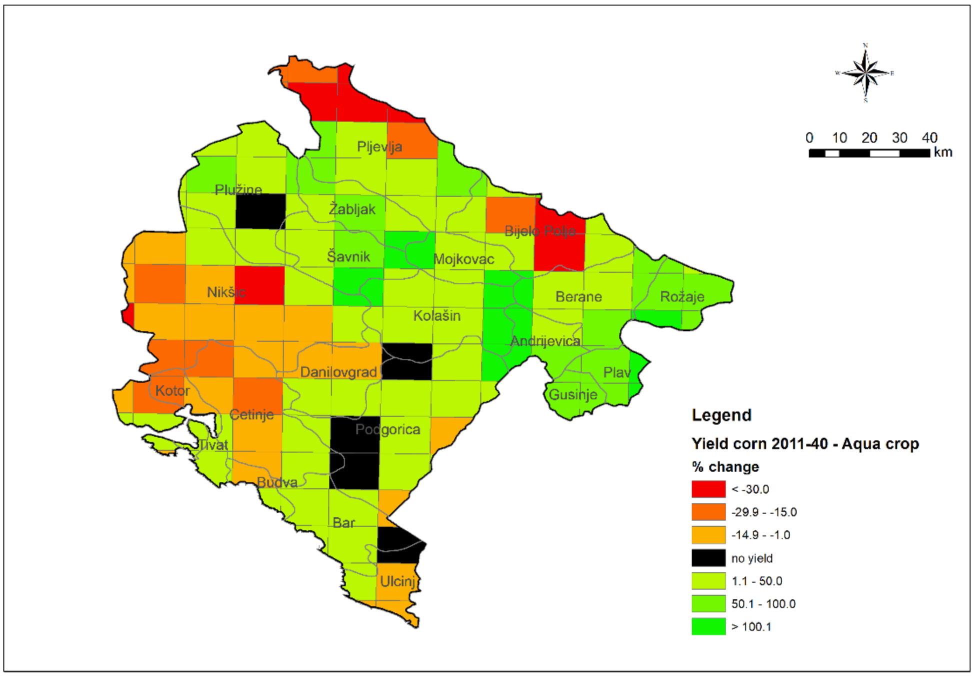
Non-irrigated maize will experience a significant positive influence on climate change in the near future (period 2011-2040). The positive effects will be prevailing in the biggest part of the country's territory. The highest positive impact on the crop yield is expected in high elevated areas in Andrijevica, Plav, Gusinje, part of Niksic, and some other areas with yield increase by more than 100%. However, the increase in the air temperature, growing season length, and some other thermal properties of the environment can not compensate for the fact that in most of the high elevated areas there is limited access to the arable land. Therefore, this impact is not helpful for agriculture in near future. However, it can contribute to the higher productivity of the high elevated grassland.

The biggest part of the country will experience an increase in the rate of 50-100%. However, some important agricultural areas will experience lower yield increase in the rank from 1 to 50%.

The yield reduction is expected for the most north and most southern parts of the country (Plevlja on the north and Ulcinj and Bar on the south) that can be even higher than 30%. Yield decrease is expected for part of Kotor, Niksic, Cetinje, Kolasin and Podgorica, but the reduction will be up to 30%.

Even though maize is quite tolerant to the heat and can efficiently use increased CO2 concentration the period 2041-2070 is characterized by a noticeable yield decrease of more than 30% in almost the whole coastal area, and in Podgorica, Cetinje, Danilovgrad, Kolasin, parts of Pluzane, Bijelo Polje and Berane. This means that climate change will be stronger than maize resilience to hot weather and elevated CO2 concentration.

A



B

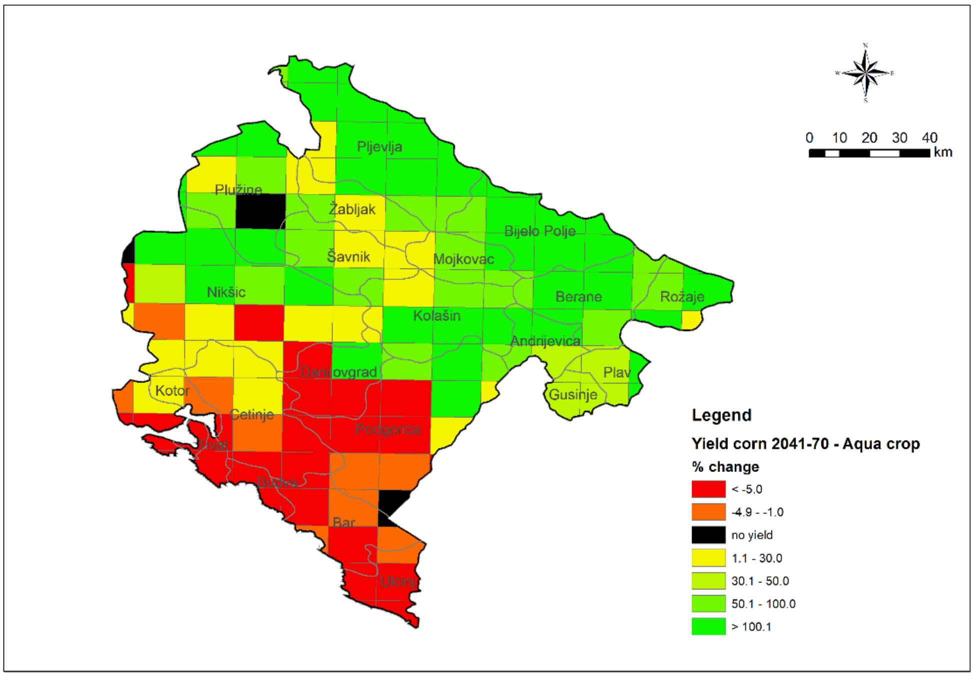


Figure 12. The average changes of the irrigated maize yield as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

Maize is typically irrigated crop, and it uses water very efficiently. However, the high yielding potential and a long growing period overlapping with the hottest period of the growing season make this crop to be considered a big user of water for irrigation. The irrigation stabilizes the crop yield and annual differences are lower compared to non-irrigated cropping. Yield decreases of irrigated maize for the period 2011-2041 is expected for the west and central part of the country including the bigger part of the Niksic, Cetinje, Kotor, and Ulcinj municipalities, north part of Danilovgrad, and the north part of Plevlja, and Bijelo Polje. However, this decrease is not as high as for winter wheat and will be more than 30% in some limited areas, and between 1 to 30% for most of the country. The increased temperature and increased CO_2 concentration in high elevated areas in the central part of the country are changing their unfavorable environment for crop cultivation and becoming more suitable for crop growing. However, the problem is that there is a very limited amount of arable land, but highland pastures can benefit from this. The increase of yield potential in these areas is even higher than 100%, however for most of the country yield will increase by a maximal 50%.

During the period 2041-2070 temperature increases and CO2 concentration will be much higher than in the near future period. Even though the maize crop can withstand higher temperatures and use water very efficiently the hottest part of Montenegro will suffer by yield decrease. Even though the yield decrease will be low, close to a maximal 5% it will affect the whole coastal region and quite fertile areas in the municipality of Podgorica and Danilovgrad. Moreover, the southern part of the Cetinje municipality will be also affected by the yield decrease of non-irrigated maize. All other parts of the country will experience a yield increase that will be from 50 to more than 100% for the northern part of the country (municipalities: Plevlja, Bijelo Polje, Berane, Rozaje, Andrijevica, Kolasin will experience the highest level of maize yield increase, followed by the Mojkovac, Plužine and Savnik).

Clearly, the irrigation strategy implemented during the modeling can be improved for the southern part of the country and combined with using of some side effects of the irrigation (cooling of the crop canopy) the results can be better than those presented in this report. However, that should be one of the topics considered for the development of the country adaptation strategies.

Potato

Potato is a crop that is characterized by quite a stable yield increase in the period 2007-2020.

The data presented in the picture below are presenting the potato yield in Montenegro for the period 2007 – 2020 (EUROSTAT).

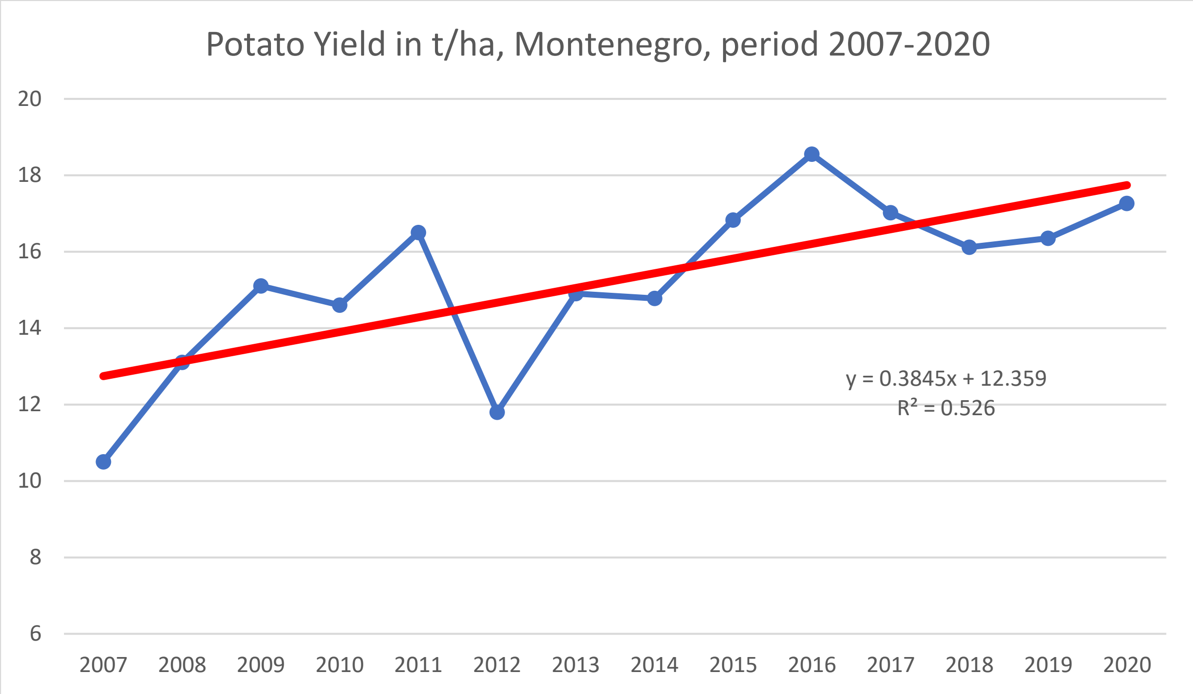
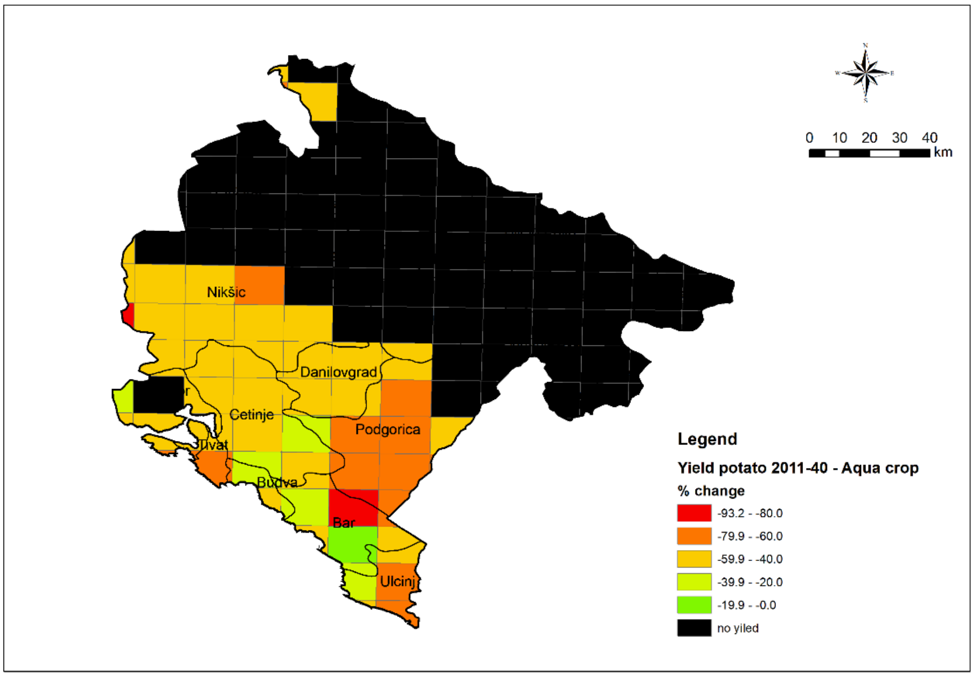


Figure 13. Potato yield in Montenegro, period 2007-2020 according to EUROSTAT

However, yield fluctuates, due to prevailing growing conditions from year to year. The results for non-irrigated potatoes are presented in the following picture. The black color is used for the areas where modeling activity gave results lower than 4t/ha even in the baseline period, or a yield that is considered as to low for a real-life situation. Presenting the relative changes for such a small yield will give the impression of the important changes, but these changes do not contribute to the profitability and welfare of the farm. The potato is planted on average 1633 ha for the period 2015-2020 and the average yield is 17,0 t/ha (Monstat).

A



B

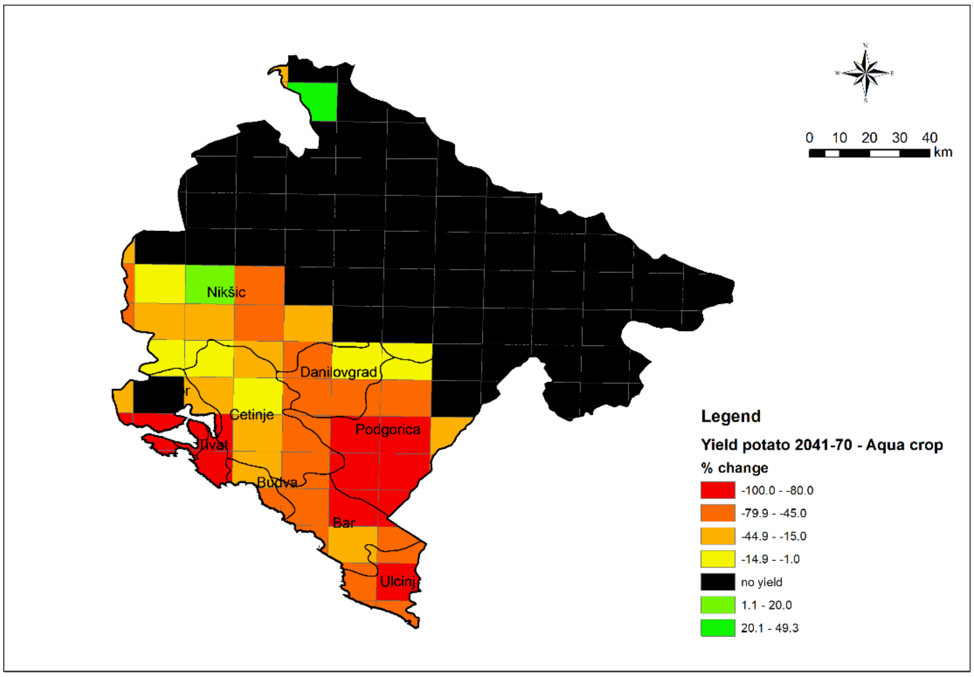
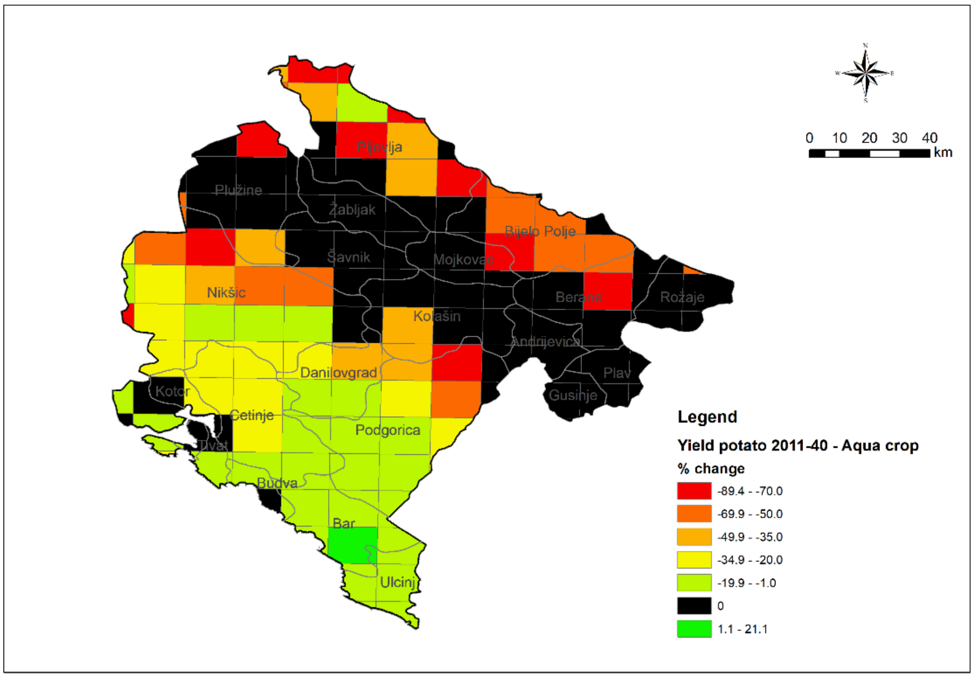


Figure 14 The average changes of the non-irrigated potato yield as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

The impact of climate change, due to the low yield modeled for the northern part of the country, can be analyzed for the coastal region and the central part of the country. However, the yield will decrease for the whole territory of the country. The smallest yield drop is expected in the coastal region by up to 40%. The yield decrease in the western part will be from 40-60%. The municipality of Podgorica will experience a yield drop from 60-80% in the near future if the potato is not irrigated. For the period 41-70 non-irrigated potato yield will drop by more than 80% in the municipality of Podgorica and Tivat and part of Ulcinj municipality. However, in certain parts of the country, the increased CO_2 level will express its effect as CO_2 fertilization and will have a positive influence on biomass productivity and yield and yield reduction will be lower than the reduction expected in near future (Niksic and Cetine municipalities).

However, potato is rarely grown without irrigation, particularly if water is available. Therefore, the following picture presents modeling results for irrigated potatoes.

A



B

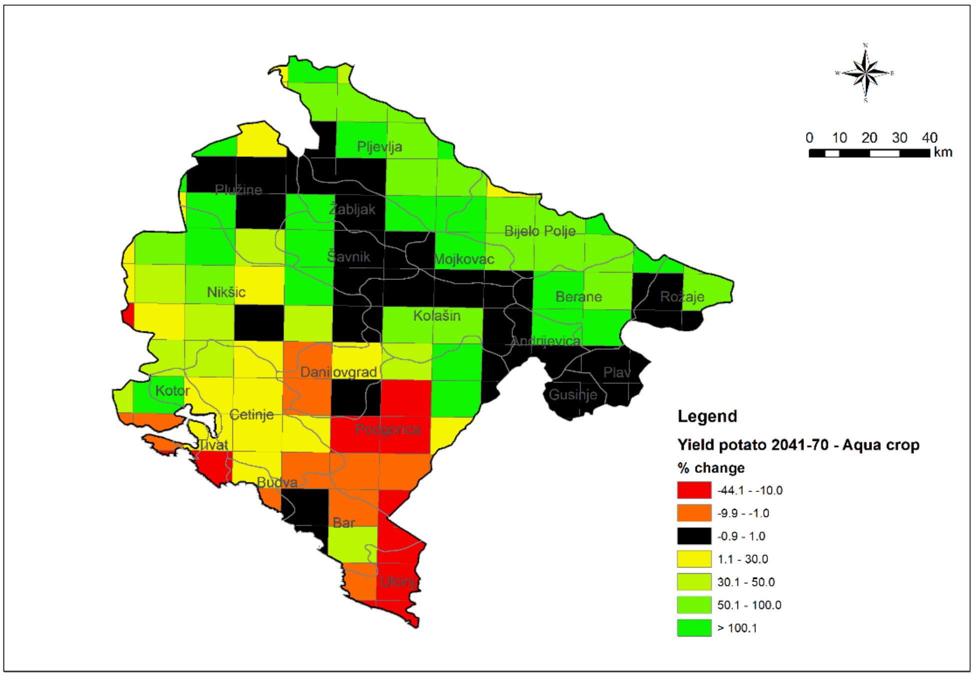


Figure 15 The average changes of the irrigated potato yield as a result of climate change, the base period 1971-2000 compared to A. near future period 211-2040 and B. future period 2041-2070

The irrigation reduces the water deficit which is one of the most severe effects of climate change on crop production in southern Europe. For the period 2011-2040, climate change will have much stronger adverse effects on irrigated potato growing in the northern part of the country, municipalities Plevlja, Bijelo Polje, Berane, Kolasin, and northern parts of the Niksic, Danilovgrad and Podgorica municipalities. The expected yield reduction will be 35-70%, and in some parts even more than 70% of yield drop. The rest of the country will experience a much lower reduction of 0 to 35%.

The period 2041-2070 completely change the picture and irrigated potato will experience an important yield increase due to the CO_2 fertilization and reduced water deficit. Therefore, the north part of the country will experience a yield increase by a minimal 30% and in some regions even more than 100%. The increase in other parts of the country is also feasible and will be from 1 to 50%. However, the yield reduction by a maximal 44% is expected in the municipalities of Danilovgrad, Podgorica, Bar, and Ulcinj. This reduction of the yield may be the result of the one irrigation strategy implemented over the whole country territory during the modeling process, which is good for the north part of the country but may not be sufficient to reduce the water deficit in the southernmost part of the country.

The irrigated potato may be successfully grown in future climates if irrigation will be considered one of the important adaptation measures. The adaptation strategy for irrigation should be carefully planned because the building of irrigation infrastructure (dams, reservoirs, conveyance, and distribution network) can be very expensive, and the return of investment can be very slow or impossible in some cases. Therefore, future activities on adaptation practices should consider irrigation and provide a more detailed analysis of the crop and irrigation water requirement in the future period.

Tomato

The tomato is probably the most produced vegetable in the world, followed by onion, cucumbers, and cabbage. Tomato is a high-yielding crop that requires intensive agricultural practices and a lot of water for irrigation. Montenegro produces tomatoes on 138 hectares and the average yield is 32,6t/ha. Tomato is sensitive to water deficit, but not as much as cucumber and peppers. Still, it needs more water than onion and cabbage. **Therefore, we can say that tomatoes can be a representative crop for the vegetable crops, or if tomatoes can be successfully grown, then almost all vegetable crops can be grown in a particular environment.**

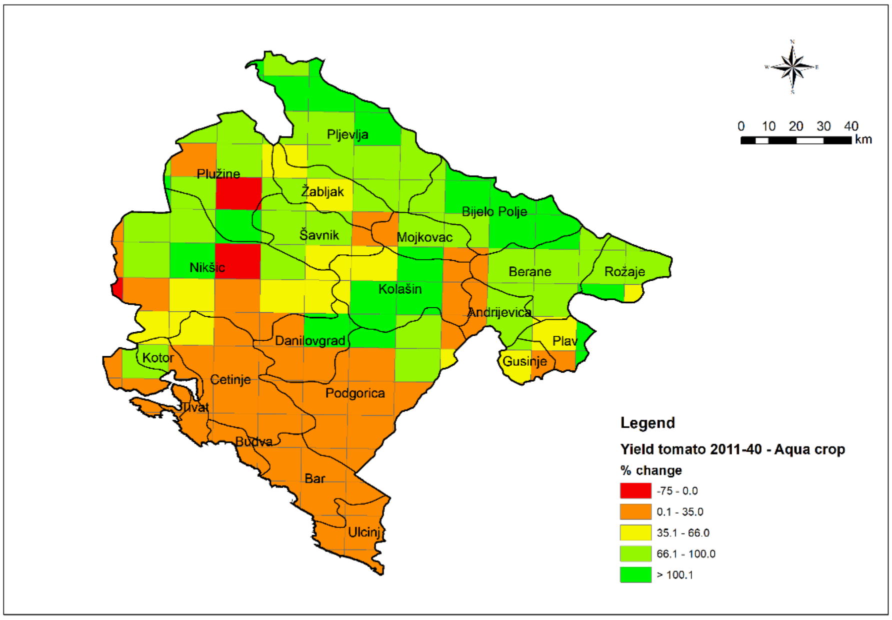
The modeling activities did not trigger any significant yield for the non-irrigated tomato in the two future periods (2011-2040 and 2041-2070). Therefore, tomatoes cannot be economically grown on open fields without irrigation in the whole country's territory. However, irrigation is quite beneficial for tomato growth in future periods. The irrigation strategy applied in the modeling process was the same for all three modeled periods and was based on the crop water requirement in the baseline period. The first look at the maps gives the impression that irrigation water contributes to the yield increase in the future period and the whole country will experience an increase in the yield of tomatoes. The lowest yield increase will take place in the whole coastal region, and most of the territory of Podgorica, Danilovgrad and Niksic municipalities. These areas will increase productivity by up to 35% of the yield in the baseline period. However, the other areas where yield response will be positive will increase yield by more than 100% in Niksic, Kolasin, Bijelo Polje, and some other parts of different municipalities. This means that climate change effects will create an environment suitable for tomato production in the parts of the country where it was not feasible to grow tomatoes because of the unfavorable conditions and low-yielding potential.

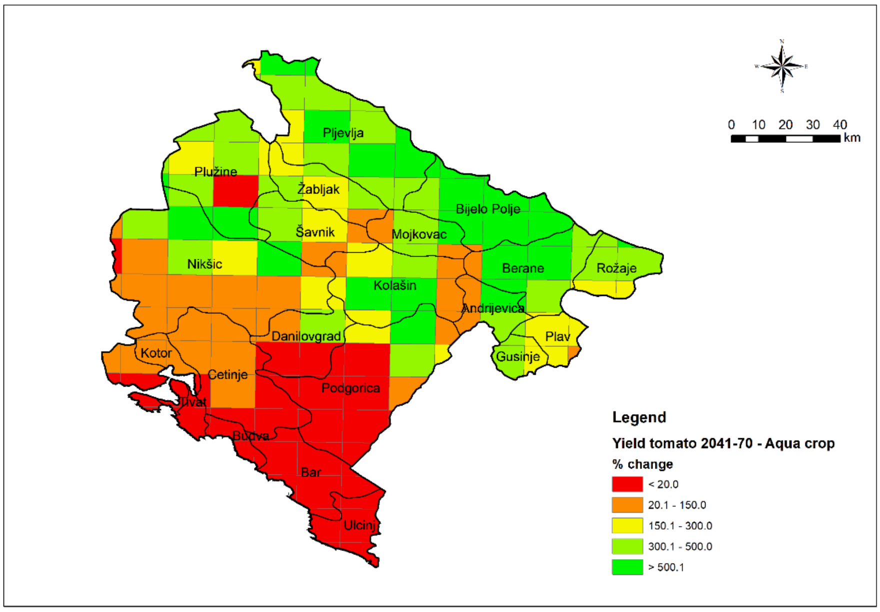
The situation during the second future period analyzed (2041-2070) is quite similar to the previous period, the yield will increase over the whole country, but the expected yield can be even 5 times higher than in the baseline period. The further increase of the temperature and

CO2 fertilization contributes to the further improvement of the environment in the north part of the country where tomato growing results are very limited in the baseline period. The smallest yield increases up to 20% will take place in the coastal region, and part of Podgorica, Cetinje, and Danilovgrad.

If non-irrigated tomatoes cannot be cultivated in future periods, irrigated tomatoes will significantly increase the yielding potential and can be successfully cultivated. Further analysis of the optimization of irrigation strategies for the south part of the country is required during the process of designing and developing the adaptation strategies and measures and much better results can be achieved. Moreover, the experience from the neighborhood shows that moving tomatoes in the protected areas (net houses, plastic houses, plastic tunnels, etc.) can contribute to minimizing the negative effects of some other damages caused by climate change (sunburns for example).

A



B	
	Figure 16 . The average changes of the irrigated tomato yield as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

Grape

The last crop that will be analyzed for vulnerability to climate change is the grape. Grape is a very important crop in agriculture in Montenegro. Unfortunately, the AquaCrop model cannot simulate non-herbaceous crops, therefore it is impossible to use AquaCrop model for this purpose. The grape yield modeling is quite complex, and new development of the models is going in direction of the multi-regression models and machine learning models. However, for this purpose, intensive datasets are required.

One of the possible solutions is to use the FAO Crop Yield Response to the Water Deficit function in order to estimate crop yield in future weather. The assumption is that water deficit will increase during the time (high confidence) and that water limitation is a major factor reducing the crop yield (high confidence), Therefore using this approach can be a reasonably good approach to estimate grape response to climate change. The same approach was used during the preparation of the Initial and Second National Communication to the UNFCC of North Macedonia, and the results obtained were confirmed in a later period using crop models (CropSyst and AquaCrop).

FAO addressed the relationship between crop yield and water use in the late seventies proposing a simple equation where relative yield reduction is related to the corresponding relative reduction in evapotranspiration (ET). Specifically, the yield response to ET is expressed as[40]:

$$\left(1-\frac{Ya}{Ym}\right)=Ky\left(1-\frac{ETa}{ETm}\right)$$

where Yx and Ya are the maximum and actual yields, ETx and ETa are the maximum and actual evapotranspiration, and Ky is a yield response factor representing the effect of a reduction in evapotranspiration on yield losses. This equation is a water production function and can be applied to all agricultural crops, i.e., herbaceous, trees and vines. The yield response factor (Ky) captures the essence of the complex linkages between production and water use by a crop, where many biological, physical, and chemical processes are involved[41]. The relationship has shown remarkable validity and allowed a workable procedure to quantify the effects of water deficits on yield[42]. This approach and the calculation procedures for estimating yield response to water were published in the FAO Irrigation and Drainage Paper No. 33 (Doorenbos and Kassam, 1979), which was considered one of FAO's milestone publications, and were used widely worldwide for a broad range of applications. Later the new knowledge and experience in the use of this function were published by FAO in the irrigation and Drainage paper No. 66 (Steduto et al., 2012). Moreover, a number of researchers were using this approach to assess water productivity in evaluating irrigation strategies, water deficit, etc.

The same approach used for North Macedonia has been also used to perform this specific assessment. The evapotranspiration (ET) in the base period calculated by FAO Cropwat software will be used as maximal evapotranspiration (ETx), and evapotranspiration calculated with the same procedure but using climate data for two future periods will be used as actual evapotranspiration (ETa). The statistical yield from MONSTAT for the period 2015-2020 will be used as maximal yield (8,47 t/ha), and the yield response factor (Ky) recommended by Doorenbos and Kassam (1979) will be used. The value of Ky for the total growing season period is 0,85. In order to have valid results for grape growing in Montenegro, the weather parameters required for ET calculation will be obtained from the grid that includes the area with the highest grape concentration in the country, south of Podgorica.

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[40] https://www.fao.org/3/i2800e/i2800e.pdf

[41] https://agrovoc.fao.org/browse/agrovoc/en/page/?clang=el

[42] https://satyukt.com/relative-crop-yield/

Using the simple calculation procedure, the actual yield in future weather conditions will be calculated, and the relative difference between baseline yield and yields in two climate change cases will be calculated and presented as a yield drop as a result of the increased water deficit due to Climate Change.

Unfortunately, this methodology is very complicated to be presented in a grid format and the results presented below address only the area chosen as a representative area for grape growing in the country.

The results obtained are presented in the table below.

Table 9. Grape yield reduction calculated by FAO Crop Yield Response to Water Deficit function

Period	Evapotranspiration for grape growing season	yield	Yield reduction from baseline
Baseline 1971-200	513.36 mm	8.47 t/ha	n/a
Near Future 2011-2049	594.26 mm	7.49 t/ha	11.57 %
Future 2041-2070	681.93 mm	6.69 t/ha	21.01 %

The results presented in the table addressed only the effect of water deficit, as a main limiting factor for crop production in future periods with foreseen climate change, Unlike the previous calculations, yield reduction is based only on one limiting factor, any other limiting factor is not addressed in this calculation. Moreover, the beneficial CO_2 fertilization is also neglected. The previous experience in the Republic of North Macedonia, using FAO Crop Yield Response to Water Deficit function, and late recalculated using the CropSyst model showed very good correlation and similarity of the results obtained by very different methodology. The assumption was that the effect of other limiting factors is compensated by yield gain from CO_2 fertilization thus similar results were obtained.

However, this simple modeling activity shows that grape yield will be reduced in both future periods. The yield reduction will be by 11,57% in near future (2011-2040) and by 21,01% in the period 2041-2070.

Livestock

CC and Livestock

Animal production as a part of the agriculture sector has not been so well researched and elaborated compared to the crop sector, in terms of vulnerability assessment to climate change. The livestock sector is more complex there are a number of technical measures implemented and developing the models for assessing productivity is a huge challenge that still needs further research. However, climate change has a severe negative effect on the livestock's productivity and welfare, reflected in frequent and prolonged heat stress. The heat stress is even more substantial on modern high-productive breeds than on local breeds adapted for ages to the local environment. All animals have a thermal comfort zone, which is a range of ambient environmental temperatures that are beneficial to physiological functions[43]. During the day, livestock keeps a body temperature within a range of ±0.5 ^{0}C.

The most important livestock type in Montenegro is the dairy cow. The effects of climate change on dairy herds is an issue that needs further research and elaboration. However, due to the increased temperature caused by climate change, the weather is going to be hotter, and the temperature will increase in the barns and shelters animals are kept or protected from outside impacts. Therefore, the livestock will be more exposed to increased temperatures.

Heat stress is considered one of the most important issues related to livestock vulnerability to climate change. Animals, as humans, are very sensitive to heat stress. The negative effects of the stress on the livestock are quite elaborated in the world literature, particularly for the cows on the heat stress can be very different. Heat loads can build when farm infrastructure doesn't provide enough protection (heat isolation), when systems for cooling and protection of the animals are not installed, when a number of animals is higher, etc. Cows take on heat from the environment and generate metabolic heat from eating and digesting feed. Problems start to occur if temperature and humidity increase, and cows don't have opportunities to balance their metabolic and environmental heat gains.

Like most mammals, the dairy cow needs to maintain its core body temperature between 38.6ºC and 39.3ºC. The core temperature changes slightly throughout the day, reaching a peak in the early evening and a low early morning. Metabolic heat is being produced all the time. During the day this heat is not as easily dispersed. If nighttime conditions are sufficient to allow adequate dispersal of heat the cow will not suffer ill effects. If this diurnal cycle of

[43] https://www.sciencedirect.com/science/article/pii/S221209631730027X

heat accumulation during the day and loss during the night is disrupted by high nighttime temperatures the effects become more noticeable.

Factors that determine the level of environmental heat a cow is exposed to over time are:

- air temperature and relative humidity
- amount of solar radiation
- degree of night cooling that occurs
- ventilation and air flow
- length of the hot conditions.

In hot environmental conditions, cows off-load heat with a range of behavioral and physiological strategies. Their response to the increased temperature is by expressing discomfort they feel and by change their behaviors by:

- looking for areas with greater air movement or standing to increase or exposure to air
- seeking water and shade
- changing their orientation to the sun
- panting or sweating, or
- stopping or reducing feed intake which decreases rumen heat production[44].

A dairy cow manages the body heat load that it carries within itself all the time. If the sum of metabolic heat produced by the cow and the heat gained from the external environment begins to exceed that lost, the cow's heat load starts to build[45].

The cow must ensure it stays within the optimal range through thermo-regulation. This means balancing the metabolic and the absorbed environmental heat using a range of strategies, such as increased breathing rate and sweating.

It is important for dairy farmers to know the signs of excessive heat load so practical strategies can be implemented to help the cows cope. The heat load is the result of the heat produced by the metabolic process and heat gained from the external environment. This load is reduced by the heat that is lost to the external environment. Once heat load reaches a critical point, changes start to occur in metabolism, hormonal regulation, and feed intake. This in turn affects milk production, milk quality, fertility, and health.

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[44] https://issuu.com/dairynewsaustralia/docs/dna_n001_tue11dec2018_lowres

[45] https://www.dairyaustralia.com.au/animal-management-and-milk-quality/animal-health/heat-stress#:~:text=Excessive%20heat%20load,heat%20load%20starts%20to%20build.

The heat stress is usually generated when infrastructure does not provide cooler conditions for the whole herd. Decreased milk production is the clearest cost, but some effects are less obvious and result in significant productivity losses. These include:

- Reduction in fertility and calving rates
- Lower milk components
- Body condition loss
- Increased susceptibility to infection.

Heat stress - Temperature Humidity Index (THI)

The erstwhile developed temperature-humidity index (THI) has been popularly used to indicate heat stress in dairy cattle and often in some other types of livestock. However, scientific literature suggests differences in thermotolerance and physiological responses to heat stress between cattle and other livestock. During the time, THI was developed to be used in number of other animals, however the principle remains the same, increasing of temperature and increase of relative humidity create discomfort in livestock and their response is quite different. Therefore, THI range used to indicate degree of heat stress in cattle should be recalibrated for indicating heat stress for each type of livestock.

Australia Dairy Association has developed several information packages related to use of THI in cattle production and to be used by the farmers without need to undertake extensive calculation procedures. The following chart can be used for quick estimation of the THI/

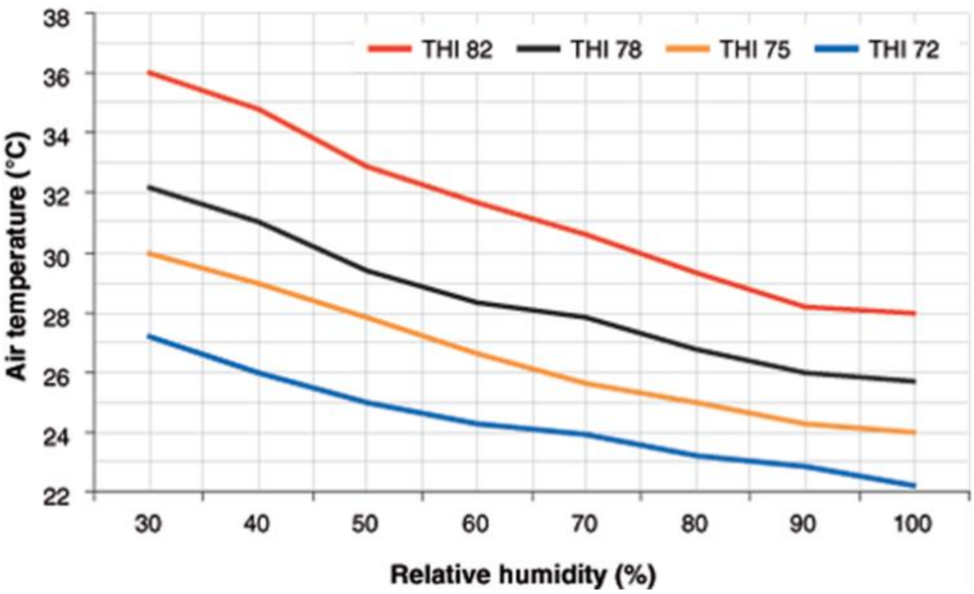


Figure 17 Chart for estimation of the THI based on air temperature and relative humidity

Because THI is a measure that accounts for the combined effects of environmental temperature and relative humidity on cattle/livestock it can be used for estimating the risk of heat stress and/or preventing major negative effects of the heat stress by undertaking some measures. There are several explanations of how to use THI values for understanding the effects. The one used for understanding the impact on cows, presented, below is sourced from Australia Dairy Association[46].

- When THI exceeds 72, cows are likely to begin experiencing heat stress and their incalf rates will be affected.
- When THI exceeds 78, cow's milk production is seriously affected.
- When THI rises above 82, very significant losses in milk production are likely, cows show signs of severe stress and may ultimately die.

A number of important points should be made about the THI:

- A THI of 72 may under-estimate heat load in high-yielding Holstein-Friesian cows – increasing milk yield increases cows' sensitivity to heat stress.
- Recent research shows that increasing milk production from 35 to 45 liters/day reduces the threshold temperature for heat stress by 5°C.
- THI does not account for solar radiation or air movement – those two factors, along with air temperature and relative humidity, determine the heat gained and lost between the cow and the environment.
- THI does not enable to measure the accumulation of heat load over time, e.g., after several days. Despite these limitations, THI is still a useful and easy way to assess and predict the risk of heat stress; however, it is wise to be conservative. If you have a herd of high-producing Holstein-Friesian, it is better to overestimate the risks of heat stress using a lower THI than get caught out.

Below are the results of the scientific modeling of the THI based on the daily Thermal Humidity Index (THI), is calculated following the formula for Cattle (Bohmanova et al., 2007)

$THIc = ((1.8\ Tmax) + 32) - ((0.55 - 0.0055\ RH) * (1.8\ Tmax - 26.8))$

[46] https://kestrelmeters.com/blogs/news?page=14

where: THIc is THIs for cattle, Tmax is the daily maximum temperature in oC, and RH is the relative humidity in percentage. Since the relative humidity was not available in the data set are not able to calculate THI. If relative humidity data will be obtained THI will be calculated.

Daily TDI was then summarized in annual THI load, representing the number of days above thresholds THI threshold value of 72 in dairy cows recently was determined as the alert phase (Pinto et al., 2020). Due to uncertainty in the approach applied, the higher threshold values of 74-78, 78-83, and 83+ were used as categories for alert, emergency, and dangerous THI load, respectively (Polsky et al., 2007). Therefore, the following THI are presented.

Table 10. THI values and their description

THI value	Description
72-78	Alert
78-83	Emergency
83+	Dangerous

The following figures/maps are representing the average differences in annual load of the number of days for different levels of THI for two future periods in Montenegro (2011-2040 and 2041-2070) compared to the baseline (1971-2000)

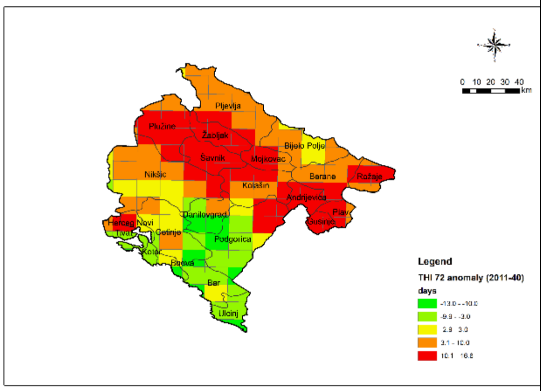
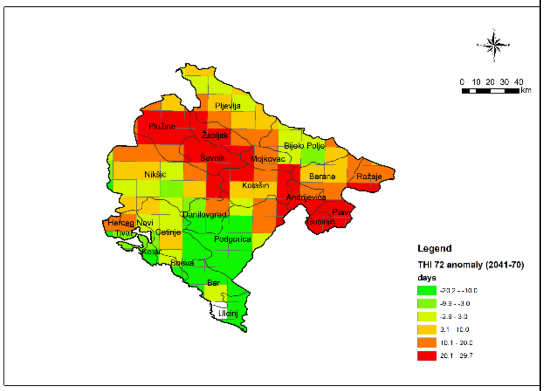
	A. Period 2011 to 2040	B. Period 2041 to 2070
THI 72-78		

Figure 18. The average changes in the number of days with THI with values 72-78 (alert stage) as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

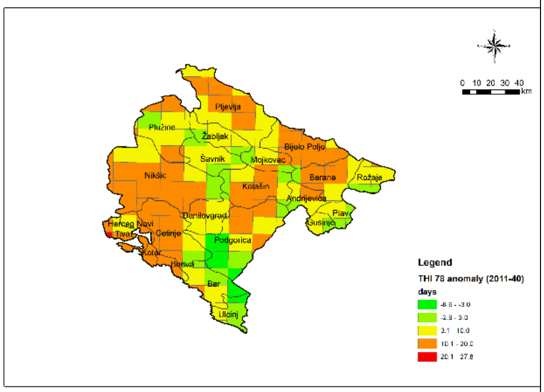
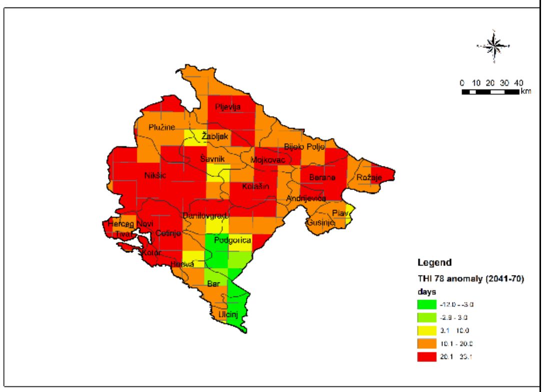
THI 78-83		

Figure 19. The average changes in the number of days with THI with values 78-83 (emergency stage) as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

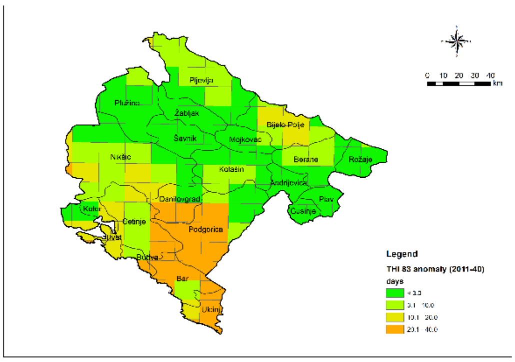
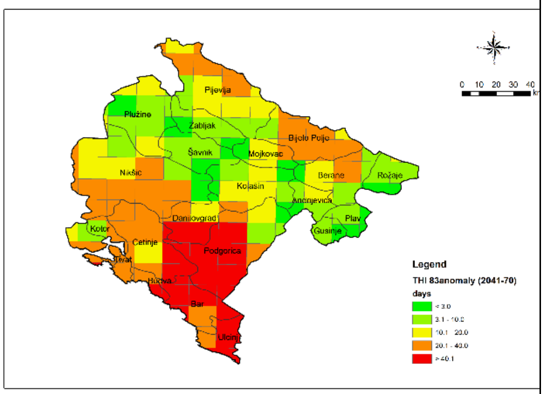
THI 83 +		

Figure 20. The average changes in the number of days with THI with values higher than 83 (dangerous stage) as a result of climate change, the base period 1971-2000 compared to A. near future period 2011-2040 and B. future period 2041-2070

The THI values between 72 and 78 are considered as an alert stage. The animals started experiencing the heat stress and feel unconfutable. Even though in this stage there is decrease in productivity, the problems with calving rate decrease are expected. During the period 2011 to 2040 the number of days with THI values from 72 to 78 Montenegro will experience the highest increase in the high elevated areas in the central and north part of the country part of the country. The increase in number of days by 10-16 days will affect the municipalities of Kolashin, Shavnik, Pluzane, Mojkovac, Andrijevica, Gusinje, Plav and parts of Rozaje, Podgorica and Niksic. The southern part of the country and municipalities of Podgorica, Danilovgrad, Budva, Kotor, Bar, Ulcinj will experience the decrease in number of days with THI 72-78 by 3 to 13 days. However, the later analyses will show that this cannot be considered as good, because when the hottest part of the country reduce number of days in alert stage, clearly the reduction is not result of better environment for cattle breeding, but opposite environment will become even less favorable and highest values will increase. The period 2041 to 2070 show very similar pattern in changes to the previous period, but changes will be more pronounced and areas that will increase will experienced increase by maximal 30 days (16 days for the previous period) and the areas where number of days will decrease will experienced even higher decrease by maximal 20 days (13 days in previous period)

However, the THI 72-78 is describing just initial effects of climate change on the livestock production. The THI index with daily values from 78 to 83 is considered as emergency stage and when these values will appear, the milk productivity will be seriously affected due to the increased level of heat stress animals will experience. The calving rate will be further decreased. Southwest part of the country (municipalities of Niksic, Cetinje, Tivat, Kotor and Budva and Northeast part with municipalities of Bijelo Polje, Berane, Kolasin and part of Podgorica, including Plevlja, on the northwest will experience the biggest increase in the number of days by 10-20 days, The parts of the country that will experience slight decrease in number of days with THI values for 78-83 by maximal 8 days are Parts of Podgorica, Ulcinj and Bar. The rest of the country will experience slight decrease of several days to medium increase up to 10 days. Further with time situation is going to be worse, and during the period 2041-2070 most of the country will experienced increasing number of days from 10 to 33 days. However, the biggest increase from 20 to 33 days is expected for Kotor, Budva Cetinje, Niksic, Nort part of Danilovgrad, and significant parts of Berane, Plevlja, Mojkovac and Kolasin.

The part that will experience decrease in number of days with THI values from 78 to 83 is reduced to the parts of Ulcinj, Bar and Podgorica.

Finally, when THI values will rise above 83 the very significant reduction in the milk productivity will appear and animals are highly stressed by heat and humidity. Prolonged period with these values can be very serious problem, animals will be under severe stress that in some cases can be fatal for some animals. The fact that whole country without exception will experience increase of number of days even in the near future (period 2011 to 2040). The biggest part of the country will experience modest increase by 3 to 10 days, but parts of Podgorica, Ulcinj, Bar, Cetinje and Danilovgrad will experience increase by 20 to 40 days, that is quite high and most of the summer period will be very stressful for livestock when heath stress is matter (increase can be almost one and the half months), that will severely reduce productivity and will have serious negative effect on the animal welfare. The period from 2041 to 2070 will further increase heat stress problems and the accumulation of days with THI above 83 will be much higher than in previous period. Therefore, the parts of Podgorica, Danilovgrad, Cetinje, Budva, Bar and Ulcinj will experience increase by more than 40 days. The increase to the level of 30 to 40 days will be in the Budva, Cetinje, Tivat, Kotor, Niksic, but also in the north of the country in the municipalities of Plevlja, Bjelo Polje, Berane and small part on the Nort Kolasin.

Nevertheless, THI analyses show that heath stress will be very serious problem of livestock production in the country, particularly cattle production. Some of affected areas are traditionally big and important producers of cheese and reduction in the milk productivity can seriously affect the farms that most of their income is coming from livestock, particularly milk and cheese. Some areas will become very unfavorable for livestock production and some measures should be foreseen to reduce negative impact of heat stress on livestock production.

Other factors that increase susceptibility to heat load

There are several other factors that affect the amount of metabolic heat a cow produces and how effectively she transfers heat to and from the external environment. Some factors are presented below.

Table 11. Other factors affecting the heat stress in cattle breeding

Coat color and type	**Black-coated cows absorb more solar radiation than cows with lighter colored coats during the day. At night, black cows will re-radiate heat more effectively. Cows with dense, flat coats resist heat transfer to the skin better than cows with woolly coats**

Temperament	Temperament may also play a small role in heat tolerance. Animals that are calmer are more heat tolerant than animals that are more excitable.
Diet	Some feeds produce more metabolic heat than others. Other dietary factors that affect the amount of metabolic heat produced include the amount of fiber versus grain/concentrates in the diet. Any restriction in the availability of fresh, cool drinking water will, of course, increase animals' susceptibility to heat stress.
Previous exposure to hot conditions	Cow that has not been preconditioned to hot weather will have a greater stress response (higher breathing rate, higher body temperature). Cows need at least three weeks to acclimatise.
Activity level	Cows that must walk longer distances over hilly terrain each day to and from the dairy generate more metabolic heat

Effects on Fertility

Fertility and calving rates can be also affected. Cows are more likely to have reduced heat expression or shortened heats in hotter seasons. This is a result of reduced activity due to heat as well as alterations in hormonal activity that reduces the expression of oestrus behavior. Heat stress has been shown to decrease oestradiol production, a major female sex hormone that regulates oestrous, leading to ovarian inactivity. Alongside this, hormonal imbalances impair oocyte development. This results in lower conception rates. Heat stress will affect the endometrium in the uterus. This can result in reduced ability to sustain a pregnancy and increased embryo mortality. Additionally, growth hormones essential to embryo development are affected by heat stress.

Higher heat loads affect digestion and nutrient acquisition by lowering feed consumption rates, which in turn can affect calf birth weight and viability. Reduced access to nutrients essential to calf development will have a negative impact on calf weight and viability. In summary, the risks to calving and fertility presented by heat stress include:

- Reduced intensity and length of oestrus
- Decreased conception rates
- Increased risk of embryo death
- Decreased calf birth weight and reduced viability.

Effects on milk

The metabolic changes associated with dissipating heat loads are energy intensive and responsible for reduced lactation and milk production. Milk from heat-stressed cows can have altered milk components with variations in proteins and fat content. A direct effect on milk quality will be due to the reduction in efficiency of the immune system resulting in an increased risk of mastitis. Care should also be taken when implementing any cooling processes with sprinklers. Wet udders when sitting in potentially contaminated areas and immediately prior to milking can result in increased contamination. Some of the risks to milk production presented by heat stress include:

- Milk production can drop by 10 to 25 per cent during heat stress, or 40 per cent in extremes
- Milk composition is affected with high to severe heat stress, with a decline in total protein
- Increased risk of udder infection, which results in increased somatic cell counts and sediments in milk.

Decreased feed intake

Feed intake and nutrition Increases in environmental temperature will suppress a cow's appetite. A noticeable difference in cows experiencing heat stress is a reduction in dry matter intake. Dry matter intake drops by 10 to 20 per cent in the short or long term, depending on the length and duration of heat stress. The effort involved with keeping cool can result in 20 to 30 per cent more maintenance energy needed to compensate. Rumination and cud chewing decreases, along with the cow's ability to digest and absorb nutrients in feed. The cow's body will open blood vessels closer to the skin's surface, so the heat load can dissipate. As a result, blood moves away from the uterus, the gut and other internal organs.

CC and livestock diseases

Climate change could have an impact on disease outbreaks in livestock. The occurrence of diseases can be directly on animals exposed to extreme weather conditions, or indirectly by the presence of vectors whose spatial distribution is usually very dependent on climatic conditions.

The direct influence of climate change is one of the preconditions of the livestock environment, that can be observed through disturbance in feeding, availability of water, and water quality, but also ensuring favorable conditions for the occurrence of many parasites and diseases. All those diseases generally do not have an impact on health status in the country, but significantly influenced the economic profitability of farming. However, some contiguous diseases are transmitted by vectors or by wild animals, and the spreading of those vectors can be enhanced by climate change. Such diseases Bluetongue, Rift valley fever, West Nile Fever, African horse sickness, African swine fever, etc. are important for determining the health status in the country. However, the occurrence of other diseases like Avian influenza is not transmitted by vectors, but they can be also related to climate change due to the change of the routes of the migratory birds. An example was in 2006 in Europe, when due to very cold weather in some regions caused frost on the open waters and lack of food for migratory birds. Consequently, seeking feed, wild birds changed their usual route of migration, so there was an outbreak of highly pathogenic Avian influenza. Increased movement of wild animals seeking feed and water also influenced the transition and spreading of contiguous diseases. There are examples of the spreading of Avian influenza, Rabies, Classical swine fever, etc. Perhaps the best examples of the influence of Climate Change on speeding the diseases in livestock are Bluetongue and West Nile fever. About 15 years ago, according to World Organization for Animal Health (OIE), each country lying above the 40th parallel north, was assumed that is free from Bluetongue disease. That was adopted based on the spread of the vector of the Bluetongue disease, the Culicoides mosquito. Accordingly, the disease had never been registered nor reported by the vast majority of the European continent, except in some very south parts. Since 2006 the disease has been speeded almost over the whole continent including Great Britain, The Netherlands, and Sweden.

The influence of climate change on frequent outbreaks of contiguous diseases that are already present, but also rather new diseases in the regions was the reason why OIE took initiative for global research on the subject. Out of 126 member countries in OIE, 71% reported a high level of concern for the expected effects, and out of them, 58% reported at least one disease that was assumed was related to climate change. The most frequent were 3 diseases, e.g., Bluetongue, Rift valley fever, West Nile fever. Therefore, the OIE initiated the strategy for support of the national veterinary services in readiness for the outbreak of the diseases.

The country was already faced with Bluetongue disease in 2014, and Lumpy skin disease in 2016. Hence, it is of vital importance to investigate the risks and vulnerability of the livestock to outbreaks of diseases that can happen due to climate change. It means to take action towards adopting farm management and technologies in preventing outbreaks, but also preventing further spreading. Also, it will influence the way of animals move (wild animals and livestock in grazing). Veterinary service needs to be trained to make early diagnose of the diseases, prevent the risk of spreading, and eradicate them. However, those activities need to be applicable, effective, appropriate, and economically reasonable. Mainly all actions will be:

• Preventive supportive measures to farmers to keep breeds with higher tolerance of diseases, and increased animal immunity, which is not always economically profitable.

• Direct measures against the pathogen and disease transmitter or vector.

• Environmental measures that prevent spreading diseases like farm biosecurity, controlled movement of animals, etc.

The current structure of national livestock production, suggest that the most vulnerable to climate change will be dairy cattle, pig. So far globally the methodological approaches have been widely applied in dairy cattle and pigs, but less in poultry. Therefore, this report aims, for the first time to assess THI for livestock thermal stress.

Livestock production is characterized by intensive production systems for large dairy cows' farms, big pig breeding farms, and layers production. Intensive production systems required genetically superior animals, strictly controlled nutrition, and an optimal ambient environment (narrowly controlled temperature, humidity, and ventilation).

Production systems in beef cattle, sheep, and goats are less intensive and closely related to near farm pastures. However, the small farmer's cattle production is also less intensive with a mixed cow-calf system. These fewer intensive systems are oriented to the local, domestic breeds of livestock and their crosses or locally adapted breeds.

Animals used for intensive production usually are more vulnerable to climate change, than local breeds, their crosses, or locally adapted breeds.

Moreover, Montenegro is characterized by so-called Katun livestock production. This production is characteristic of the mountainous part mainly in the north part of Montenegro. The production is based on the utilization of mountain pastures. When the snowpack melted and grass began to grow on the mountains, local people would move the village's livestock up the mountain. The animals would graze on highland grasses among the katun mountain hut areas during the summer and early fall months[47]. During this time, the village grass was allowed to grow for future use. Katuns are located in high elevated areas, where because the temperature gradient temperature is lower, thus animals are less exposed and less vulnerable to heat stress. Katun production is a good option for reducing the impact of climate change. There will be higher biomass productivity in the higher elevated areas due to the prolonged growing season and increased temperature and CO2 concentration. This means the feed will be more available, the heat stress risk is minimized and higher productivity of katun breeding

[47] https://meanderbug.com/katun-the-essence-of-montenegrin-culture//

animals is feasible. However, the number of katuns is reducing and measures for protecting katun production should be correlated to climate change adaptation as well.

Cow health and infections

Hot and humid conditions created after a summer storm or sprinkler use present two main challenges to managing cow health:

- Maintaining the pH of rumen to prevent ruminal acidosis and ketosis
- Suppressed immune function alongside exposure to sources of opportunistic infection.

Large downpours over summer can quickly push up humidity in hot conditions and reduce the effectiveness of sweating as a form of evaporative cooling for cows. As heat loads increase because of this, the cow will increase their breathing rate and begin drooling. Saliva loss reduces the rumen pH because the bicarbonates in cow saliva can't act as a buffer to the rumen's acidity. This can be further impacted by feeding strategies. Heat stress also reduces the cows' dry matter intake (DMI), grazing during the day, and cud chewing. The natural process of rumen buffering through rumination and saliva bicarbonate is impaired. This is a common cause of subacute ruminal acidosis (SARA). In hot weather, cows prefer to eat in blocks in the cooler times of the morning and evening. This will often be when in the dairy being offered high starch bail feed. Cows tend to select against low quality forage/fiber if it is offered to them. They are less likely to use this to aid rumen balance than they would good quality forage. Additionally, a reduction in DMI can push metabolic energy sources from carbohydrates toward fats due to increase body tissue breakdown (ketosis). This will also contribute to metabolic acidosis. SARA plays a key role in the complex causes and origins of laminitis and associated diseases, such as claw lesions, white line disease, ulcers and lameness. Cows will roll and wallow in mud to alleviate heat loads and this presents a risk of environmental mastitis and other infections. In summary, some of the risks to cow health presented by heat stress include:

- Decreased rumen buffering capacity
- Decreased rumen pH
- Increased ruminal acidosis and ketosis
- Increased laminitis
- Suppressed immune function, increasing susceptibility to infectious diseases
- Increased mastitis

Beekeeping

The European honeybee, Apis mellifera, is the most economically valuable pollinator of agricultural crops worldwide[48]. Bees are also crucial in maintaining biodiversity by pollinating numerous plant species whose fertilization requires an obligatory pollinator. However, beekeeping is considered a valuable agricultural activity and the aim is honey production as well as the production of bees' by-products that can be important income in rural areas.

Apis mellifera is a species that has shown great adaptive potential, as it is found almost everywhere in the world and in highly diverse climates[49]. In the context of climate change, the variability of the honeybee's life-history traits as regards temperature, and the environment shows that the species possesses such plasticity and genetic variability that this could give rise to the selection of development cycles suited to new environmental conditions. Although individual bees are vulnerable to environmental stressors, the honeybee colony as a whole is more resilient and can accumulate contaminants or respond to climate change without collapsing.

However, the climate changes are adversely affecting the agricultural sector in general and apiculture particularly. Honey production is one of the most sensitive parts of agricultural practices which are directly or indirectly affected by climate variability such as temperature, precipitation, rainfall, flooding, drought, etc. In particular, climate change contributes to the decline in pollinators, including honeybees, and damage to harmonization between pollinator activity and flowering. The production of honey has been extensively affected by the warming aspect of climate change. The honeybee development cycle can be influenced by climate change, and it is generally agreed that each race of honeybees grows at its own rate. According to, Conte & Navajas (2008), honeybees move from one geographical region to an unknown area during any kind of climate change, and therefore, are sure to have measurable consequences. During the harsh season, honeybees store their honey to provide them with the energy they need to survive until favorable conditions come for them. Due to these reasons, honey production and productivity became decreased, and the income generated from honey became declined which negatively affects the economy of one country and even more important the livelihoods of the community who rely on honey production. Among the environmental factors that may impact the delivery of provisioning services by honeybees is climate change as the observed variation in honeybee abundance and honey yields along climatic gradients proposes. Temperature and to lesser degree precipitation seem to exert

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[48] https://pubmed.ncbi.nlm.nih.gov/18819674/

[49] https://pubmed.ncbi.nlm.nih.gov/18819674/

primary control on honeybee activity, yet the extent to which climate change will impact honey yields is poorly understood.

The impact on honeybees as a result of climate change is diverse and still needs further research, even though there is a large body of data indicating that environmental changes have a direct influence on honeybee development. Since the late 1990s, beekeepers around the world have noticed the disappearance of bees and reported unusually high rates of decline in the number of bee colonies. The main reasons for the global decline in the number of bees are related to industrial agriculture, parasites/pathogens, and climate change. The loss of biodiversity due to monocultures and the widespread use of pesticides that kill bees pose a particular threat to bees and wild pollinators. Bees are not the only pollinating insects in the world, but they are vital for crops such as alfalfa, almonds, cucumbers and strawberries and many others.

In the EU, the general trend has been a decrease in the population of bees in the north/west and a slight increase in the south/east with significant spatial and temporal variations. The EU policies related to honey production intensified in the last period and there is an increase in the budget for the period 2020-2022 (Honey (europa.eu)). Various scientific studies have pointed to a decline in bee populations due to a long list of possible threats:

- habitat destruction;
- abuse of pesticides, which are now temporarily banned in the EU;
- invasive species such as the Asian hornet attacking hives;
- Varoa, which sucks the nectar of bees;
- Nosema apis parasite, which interferes with their digestive tract; and, last but not least,
- climate change.

Therefore, the EU supports the development of a national apiculture programms. Under the programms, eight specific measures are eligible for funding[50]:

- technical assistance, such as training for beekeepers and groups of beekeepers on topics such as breeding or disease prevention, extraction, storage, packaging of honey, etc.;
- combatting beehive invaders and diseases, particularly varroosis (varroa is an endemic parasite, which weakens bee immune systems and can lead to the loss of bee colonies)[51];

[50] https://agriculture.ec.europa.eu/farming/animal-products/honey_en

[51] https://www.cde.ual.es/en/apiculture-in-the-european-union/

- rationalisation of transhumance, through the provision of relevant information and materials;
- analyses of apiculture products, such as honey, royal jelly, propolis, pollen, and beeswax;
- restocking of hives;
- applied research;
- market monitoring;
- enhancement of product quality with a view to exploiting the potential of apiculture products on the market.

Montenegro is a country with a high level of approximation to EU policies and legislation, and the above-mentioned measures proposed are a good opportunity to improve climate change adaptive capacities among beekeepers in the country. The beekeeping sector has been recognized by the Montenegrin government as one of the most important parts of agriculture. The Ministry of Agriculture and Rural Development envisaged beekeeping among the main sectors of future growth and support under the instruments planned in the Programme for the development of agricultural and rural areas in Montenegro IPARD II 2014-2020 (June 2015) as well as in the Strategy for the Development of Agriculture and Rural Areas 2015-2020.

The importance of beekeeping lies not only in the production of honey and other bee products but also in increasing the role of bees in plant pollination, thereby directly affecting the increase in the yield of agricultural plants. In the 2010 Census of Agriculture, there were 2,533 family landfills engaged in bee breeding, while the total amount of hives in Montenegro was 50,024.

The first available data show that at the end of the XIX century there were already about 15000 hives in Montenegro. It is estimated that after the Second World War there were more than 40,000 bee colonies and that from 1950 to 2005 there was a steady increase in honey production. Since the beginning of the sixties, significant investments in equipping beekeeping began, as well as the education of beekeepers.

The warm and sunny climate in Montenegro is accompanied by the presence of large water areas (Adriatic Sea, Lake Shkodra), deep sea drawback into the coast (Boka Kotor Bay), moderately high mountainous hinterland near the coast (Orjen, Lovcen, and Rumia Mountains), Ulcinj field in the far southeastern part and mountain ranges of Durmitor, Bjelasica, and Prokletija. The southern part of Montenegro and the Zetsko-Bjelopavlić Valley is located in the Mediterranean climatic area (long, warm, and dry summers and relatively mild and rainy winters). The towns located in the continental part such as Podgorica and Danilovgrad, in January have lower temperatures than coastal towns located at relatively the same latitude, while the temperature during the summer is higher.

The hottest summers in Montenegro are in the Zetska Plain, due to a large number of clear days during the summer, which makes the country and the air very warm. The lowest mean annual temperature is on Žabljak (Tara River basin). The large karst valleys have a harsher climate, the bottom of which is deep below the surrounding mountain peaks, and which are 40 to 80 km away from the Adriatic. Such climatic conditions, at a very short distance and under the influence of the proximity of the Adriatic Sea and local relief, change from the Mediterranean to subcontinental and continental, are very useful for beekeeping because they allow different types of plant cultivation.

In addition to the favorable natural condition (climate, relief, orography…) there is a large variety of honey plants, as another significant factor in the production of high-quality honey. Different altitude relationships, the slope of the terrain, and exposure to the sun give honey a special feature that further affects the quality and creates special honey.

For many years, a Kranjska bee (Apis mellifera carnica) is grown in Montenegro, which is normally grown in almost the entire area southeast of the Alps, i.e., in the Balkan peninsula countries. In different ambient (geographical and climatic) conditions, more varieties or ecotypes of Kranjska bees were differentiated over time. Due to the benefits of breeding this breed of bees in Montenegro, the Law on Livestock (Sl. List CG 72/10) defines the Kranjska bee as the only desirable and permitted breed of bees in Montenegro. The Kranjska bee spends winters in a small flock with relatively modest food supplies, but its development in the spring occurs abruptly, and the colonies sometimes reach their peak already in May. The Kranjska bee is popular among beekeepers for several reasons, mostly because of its ability to successfully defend itself from insect pests, while at the same time it is extremely gentle in its behavior towards beekeepers.

The honey production in Montenegro is based on multi-flowered honey. The reason for this is the presence of over 500 species of honey plants, many of which are medicinal plants. The following map shows the different types of plants in different parts of Montenegro.

Figure 21 The important plant species for bee keeping and their distribution in Montenegro

It is obvious that Montenegro has very good environmental conditions for beekeeping and for the production of honey with some special properties that can be an advantage compared to honey coming from other areas in Europe.

Nevertheless, Montenegro beekeeping is quite intensive, compared to some other agricultural activities (crop production for example). The data below are presented from the Study conducted in 2019 for the assessment of the apicultural sector and possibilities for the development of the National Apicultural Programme. The study pointed out that about 2500 beekeepers are registered in Beekeeping societies. However, a number of beekeepers are not members of any society, and by using the survey methodology the authors concluded that the number of beekeepers is 3672, but only 73 of them are big producers with 150 and more beehives. The total number of hives is defined as 65 thousand and average honey production per hive is 11,7 kg and the average cost of the production is 7,7 EUR/kg of honey. The price of the honey depends if it is marketed on the spot of the production or wholesale and can range from 5 Eur/kg to 16 EUR/kg with an average price close to 10 EUR/kg.

Table 12. Summary table of the beekeeping sector in Montenegro

Categories	Value
number of beekeepers	3,672
number of beekeepers with more than 150 hives	73
total amount of hives in the farms with more than 150 hives	18,837
number of beekeepers organized in beekeepers' associations	2,442
annual national honey production per kg in the last two calendar years; Year 1	390,000 kg
annual national honey production per kg in the last two calendar years; Year 2	627,000 kg
the price range for multi-flowered honey at the point of manufacture; Average value	10,60 EUR/kg
the price range for multi-flowered honey at the point of manufacture; Minimum value	7.00EUR/kg
the price range for multi-flowered honey at the point of manufacture; the maximum value	15,00 EUR/kg
the price range of multi-flowered honey wholesale; Average value	10,03 EUR/kg
the price range of multi-flowered honey wholesale; Minimum value	5,00 EUR/kg
the price range of multi-flowered honey wholesale; Maximum Value	€16.00/kg
estimated average honey yield per kg per hive and annually	11.7 kg
estimated average production costs (fixed and variable) per kg of honey produced	7,7 EUR/kg
number of hives [2017]	65,000

Source: Studija o strukturi proizvodnje i stavljanju na tržište meda i drugih pčelinjih proizvoda kao osnove za razvoj Nacionalnog pčelarskog programa Crne Gore cited European Commision; Quantitative PAPI / CAWI Survey of Beekeeping Montenegro, March 2019; MONSTAT

However, the effects of the production factors (including climate) on productivity can be analyzed only by using time series. The following table presents the number of beehives, annual production on the country scale as well as annual productivity expressed in kg/beehive.

Table 13. Summary table of the beekeeping sector in Montenegro

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of beehives	42237	42680	42458	43210	48007	67703	65000	67908	68608	70022
Total annual honey production in t	394	554	510	325	489	627	390	688	604	335
Average production per beehive in kg	9	13	12	8	10	9,2	6	10	8.8	4.8

Source: Studija o strukturi proizvodnje i stavljanju na tržište meda i drugih pčelinjih proizvoda kao osnove za razvoj Nacionalnog pčelarskog programa Crne Gore and MONSTAT, Annual Statistical Yearbook 2021

The number of beehives rose from 42237 in the year 2011 to 70022 in the year 2020, which is a clear sign of existing interest in beekeeping in the country. However, the production is not strongly associated with the number of hives and fluctuated from 325 t in the year 2010 (43210 beehives) to 688 t in 2018 (67908 beehives). The year 2017 and 2020 are characterized by the lowest productivity of 6 and 4,8 kg/ha respectively.

The Drought monitoring bulletin, published by DMCSEE for the season January-October 2020 (450_dmcsee_bulletin_season2020.pdf) shows that Montenegro experienced an unusual temperature anomaly in February exceeding the long-term average by up to 1.5 °C which contribute to the experienced dry water balance situation for up to 160mm. Moreover, April was one of the driest April months ever on the North and West Balkan peninsula. Lack of rain throughout all month resulted in an accumulated monthly deficit of mostly up to 100 mm, locally along the western parts from Slovenia to Montenegro. May brought rapid changes from one extreme to another. It resulted in a monthly mean of up to 1 °C colder than normal was colder than normal throughout all month. The colder than usual weather continued in June as well. The early season hot and dry period from February to April, followed by lower than usual temperatures in May and June resulted in the lowest honeybee productivity in the period observed. Similarly, the very low productivity in the year 2017 was also weather-induced when the whole Balkan Peninsula, including Montenegro, experienced two sets of droughts in March 2017 and August 2017 (DMCSEE - 430_dmcsee_bulletin_season2017.pdf). Dry winter months along with above-average air temperatures resulted in spring drought across the region. It greatly reduced good sowing conditions and set the ground for the following summer drought. In spite of some cold and wet periods in late spring, drought intensified in early summer through several heat waves and scarce precipitation levels. It reached its peak early in August

It is clear that Montenegro beekeeping and honey production highly depend on climate particularly prone to high temperatures and drought. The impact of climate change on honeybees and their productivity, combined with low adaptation capacities or even impossibility to adapt, causes high vulnerability of the beekeeping sector.

Increased temperature causes rapid changes in plant/crop growth. The phenological calendar is changing due to the increased temperatures and faster temperature accumulation. Each plant species requires a certain temperature accumulation to move from one growth stage to the next one.

The increased temperature rises the temperature accumulation speed and growth stages of the plants are starting earlier and last for a shorter period. Therefore, the whole growth cycle of the crops/plants is faster. The growth stages are forced to pass for a shorter period and there is not enough time to complete processes, biomass accumulation is lower and appeared in a different time span compared to the base period. This is valid for flowering as well because it is one of the growth stages, that will appear in different periods and will last for a shorter time. Natural vegetation will migrate to the higher elevation, therefore the floristic composition of the riparian zones, meadows, pastures, and other zones populated by natural vegetation is at risk of changing composition, some plants will move from these zones, and some new will appear. Therefore, the honeybees will be vulnerable to the reduction and changes in their food sources, access to the food will be reduced and the risk of accumulation of enough food for wintering is increasing. Any of these components can reduce the productivity of the honeybees, as well as influence the higher rate of bee mortality.

The drought is an important driver of reduction of the bee productivity. The dry weather reduces the crop growth, dries the pollen and nectar, and reduces honeybees' food availability.

Climate change can influence the honeybee development cycle. It is generally agreed that each race of honeybees develop at its own rate. Any sort of climate change or movement of a race of honeybees from one geographical region to an alien one is therefore bound to have measurable consequences. In cool regions, honeybees spend the winter clustered in a tight ball and use their honey stores to provide them with the energy they need to survive until spring. The honeybee's capacity to accumulate energy reserves and manage the colony's development exerts significant adaptive pressure. In the spring, when the weather becomes more clement, the queen starts to lay eggs and the colony develops and increases the size of the worker population. A cold snap lasting several weeks may occur during which the honeybees are unable to harvest. The large size of the honeybee population causes such a rapid depletion of stores that the colony can die of starvation without the assistance of a beekeeper to provide them with unlimited supplies of sugar solution. Local ecotypes that are better adapted to the environmental conditions are more cautious and develop more slowly in spring until after this cold snap when they breed very rapidly. In this way, they avoid jeopardizing the colony's survival. A distinction, therefore, needs to be made between local ecotypes, which need to adjust their development and stores to the climate. The variability of the honeybee's life history traits as regards temperature and the environment shows such plasticity and genetic variability that this could give rise to the selection of development cycles suited to new climatic conditions.

Potential for adaptation: genetic variability

Bees adjust their behavior to weather conditions. They do not go out when it rains and, in extremely hot weather, they gather water to keep the colony cool.

Apis mellifera is a species that has shown great adaptive capacity, as it is found almost everywhere in the world and in highly diverse climates. Imported to the Americas by the colonists, it has co-evolved with humans and has spread throughout the continent, from north to south. It may be assumed that, as the species has great biodiversity, it will be able to use its genetic variability to adapt to climate change. Humans, with whom Apis mellifera has co-evolved for several centuries, will certainly be decisive in helping honeybees to survive in hostile environments and in preserving the biodiversity of these species. Beekeeping is an essential pollination and production support tool in this respect. However, if bee ecotypes are no longer suited to their biotopes, feral colonies will need to evolve rapidly to survive without human assistance

Mismatch In Seasonal Timing is one of the problems associated with climate change and the role of the bee in the environment and agriculture**.** The honeybees' role as pollinators is essential for the crops and natural vegetation, their survival, and their productivity. For this role, timing is a crucial factor for bees. The time of flowering and hatching must coincide for successful pollination to take place. Naturally, bees usually come out of winter hibernation at exactly the same time when flowers begin to bloom. However, increased temperature causes an increase in the temperature accumulation that affects plant growth, usually with advances in their development, and shorter duration of the growth stages (flowering as well). Moreover, the honeybees are also affected by higher temperatures, but their response is not coordinated with the plant response to increased temperature and faster temperature accumulation. Therefore, climate change has resulted in the mismatch between the period when flowers produce pollen and when the bees are ready to feed on the pollen

Habitat Loss is an important problem associated to climate change. Studies indicate that bee territories have shrunk by nearly 320 miles in North America and Europe. Consequently, the habitat ranges for the honeybees have become smaller and they are challenged as to where they should set their hives. Unlike other insects like butterflies that easily adapt to new habitat ranges in cases such as the current climate change, some bee species like bumblebees rarely shift their habitat. Thus, habitat loss may eventually result in the extinction of some species of bees[52].

An Increase in Susceptibility to Diseases Bees is vulnerable to some species of gut and mite parasites that thrive in warm temperatures. One of the glaring effects of climate change is the increase in temperatures and fewer cold seasons. These high temperatures mean that bees are at greater risk of diseases and parasites now than they were before due to climate change[53]. Moreover, new diseases, pests, or parasites from Southern regions can spread their areal to the North and accelerate the risk to honeybees' health, survival, and productivity.

Altering the Scents of Plants Honeybees recognized their food source according to the floral scents that are unique to each flower and plant. Bees have a special ability to store these cues in their memory and utilize them in their search for pollen for food. However, climate change has resulted in plants changing their scents. The reason for this is that changes in the environmental conditions (such as lack of water or extreme heat) result in plants being stressed. Consequently, they release defensive compounds to protect them from harm[54]. It is these compounds that alter the scents of these plants making it difficult for bees to trace their way to plants for food. The lack of food results in the loss of bee colonies.

Reduction in protein content of the pollen – the increased level of carbon, changes C:N (carbon to nitrogen) ratio in the pollen, thus fewer proteins are accumulated due to the increased carbon-based assimilates. The shortage of protein access for the bees can cause malnutrition and decrease their health status, thus reducing the survival rate during wintering, and increasing the loss of colonies is very possible.

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[52] https://www.worldatlas.com/articles/how-does-climate-change-affect-bees.html

[53] https://www.worldatlas.com/articles/how-does-climate-change-affect-bees.html

[54] https://www.worldatlas.com/articles/how-does-climate-change-affect-bees.html

Farmer's perception - Some recent research (Vercelli at al., 2021) reported the farmers' perception of the problems associated with climate change and beekeeping. Beekeepers reported several consequences related to severe weather events (weakening or loss of colonies; scarcity of nectar, pollen, and honeydew; decrease or lack of honey and other bee products[55]; greater infestation by varroa; decline in pollination), making it necessary to provide supplemental sugar feeding, intensive transhumance, more effective and sustainable techniques for varroa control, and increased production of nuclei. Thanks to their strong motivation and collaborative attitude, beekeepers succeed in adopting farm and beehive adaptation strategies that are able to limit the climatic adverse effects. However, these findings highlight how the institutional and financial support for the beekeeping sector should be strengthened and better targeted[56].

5.2. Risk assessment for macro-regions

As a candidate country of the European Union, Montenegro (ME) is included in the Nomenclature of Territorial Units for Statistics (NUTS). The three NUTS levels are: NUTS-1: ME0 Montenegro; NUTS-2: ME00 Montenegro; NUTS-3: ME000 Montenegro[57]. Therefore, the subdivision using NUTS is not possible. Below the NUTS levels, there are two Local Administrative Units (LAU) levels: LAU-1: municipalities and LAU-2: settlements. The subdivision on LAU-1 level is presented in table below.

Table 14 Local Administrative Units at first level (LAU-1) for Montenegro, area, population and population density, Source Monstat

	Municipality	Area in Km^2	Population 2021	Population density Inhabitants/ km2
1	Andrijevica	283	4403	16
2	Bar	598	44054	74
3	Berane	544	26013	48
4	Bijelo Polje	924	41018	44
5	Budva	122	22660	186

[55] https://pubmed.ncbi.nlm.nih.gov/33800740//

[56] https://pubmed.ncbi.nlm.nih.gov/33800740/

[57] https://everything.explained.today/%5C/NUTS_of_Montenegro//

6	Cetinje	899	14923	17
7	Danilovgrad	501	18305	37
8	Gusinje	157	3995	25
9	Herceg Novi	235	30356	129
10	Kolašin	897	6943	8
11	Kotor	335	22713	68
12	Mojkovac	367	7232	20
13	Nikšić	2,065	68172	33
14	Petnjica	173	5275	30
15	Plav	328	8191	25
16	Pljevlja	1,346	25917	19
17	Plužine	854	2485	3
18	Podgorica	1,399	191637	137
19	Rožaje	432	22926	53
20	Šavnik	553	1424	3
21	Tivat	46	15248	331
22	Tuzi	236	12344	52
23	Ulcinj	255	19991	78
24	Žabljak	445	2986	7

Therefore, the territory of Montenegro for administrative and statistical purposes is divided in 24 municipalities. The basic data presented in this table, however our attempt to collect population projections from MONSTAT website was not successful because projections are presented by regions (South, Middle and North). We believe that number of data is available at municipality level. Even though we were not able to determine it.

For proper risk assessment number of data have to be associated to the table above, including rural population, gender, projected population (including rural), agricultural land, cropping pattern, number of livestock, socio economic indicators (all of them present and projected).

The climate and climate change including quantified impact on agricultural productivity can be assessed by modeling and later aggregated to the municipality level.

Therefore, in shortage of data, particularly disaggregated to the municipality level it is very hard to do projections for macro regions for the future periods.

The matrices below present risk assessment on the country level, based on the analyses conducted during this process and some expert judgment.

Table 15. Risk assessment for the near future compared to base case for Montenegro

Indicator	Near Future /Base Case
Temperature increase	
Annual rainfall decrease	
Drought - Aridity index by UNESCO	
Extreme weather events	
Temperature Humidity Index (THI),	
Irrigated land	
Cultivated land	
New diseases and pests in crops	
Number of livestock	
Fodder Availability for Livestock	
New diseases and pests in Livestock	
Area under certain crops	
Number of rural populations	
Soil organic matter in the topsoil	
Erosion risk	
Average farm size	
Number of agricultural holdings	

Age structure of farmers	Red
Level of education of farmers	Red
Farm size by economic class	Green
Number of research papers in Scopus (or WoS) in agriculture	Yellow

Worse than Base case	Red
Similar to Base Case	Yellow
Better than Base Case	Green

Out of 21 indicators, 10 indicators are going to be worse, 5 will be similar to the base case and 6 are going to have positive anomaly in the near future. Therefore, we can say that risks for the near future will be higher.

Such analyses should be conducted at municipality level in order to assess the risks on the municipality level.

5.3. Future vulnerability of the sector agriculture

Based on the analyses conducted, modeling activities and experience in the region we can say that Montenegrin agriculture is quite vulnerable on climate change.

As first of all exposure is high and climate change will express its negative effects similar to the other Mediterranean and south European countries that will be the most affected countries in Europe. According to the Report on the future climate projections and analysis of the extreme weather effects and climate happenings, prepared by Dr. Vladimir Djurdjevic there are a number of anomalies in the future weather that pose a significant risk for disturbing agricultural production and productivity. The report presents seasonal changes of weather/climate elements on the territory of Montenegro for three future weather horizons, 2011–2040, 2041–2070. and 2071–2100 in relation to the reference period 1971–2000.

For the future period 2011–2040. the deviation of the mean annual temperatures in relation to the reference period according to this scenario is from 1.5 to 2 ° C. For the DJF season, the deviations are slightly larger and for most of the territory are from 2 to 2.5 ° C, while the deviations for the JJA season for the whole territory are on average about 2 ° C. For the period

2041–2070. deviations of the mean annual temperature range from 2.5 to 3 ° C, while the deviations for the DJF and JJA seasons are on average the same, with the deviations being higher in the north for the winter season (DJF) and higher in the south for the summer season.

For the period 2011–2040. the deviation of the mean annual precipitation in relation to the reference period in the north of the country is positive, and for the most part up to + 5%, while in the southern part of the country it is negative and for the most part up to –5%. For the DJF season, the spatial distribution of deviations is similar to the change in annual precipitation with a slightly more pronounced positive change in the north, while deviations for the JJA season have a slightly more pronounced negative change in the southeast. For the period 2041–2070. deviations of mean annual precipitation are negative throughout the territory with a maximum of –20%. For the DJF season, the changes are similar to the changes during the period 2011–2040, while the JJA season was characterized by a negative anomaly of up to –45%. Such a pronounced negative change is obviously responsible for the existence of negative change on an annual basis.

The intensity of the rainfall is assessed as a number of days with rainfall accumulation higher than 20 mm/day. However, an increase in the number of these days can be expected in the far north of the country with maximum values greater than 80%. For the case of the period 2011–2040. during the JJA season, the change is positive in the west, northwest and southeast of the country, and negative in the east and on one part of the Adriatic coast. For the periods 2041–2070. and 2071–2100. the change in the RR20 index for the JJA season is negative in almost the entire territory with a maximum value greater than –80%, while in most parts of the territory this change is up to –80%.

The number of consecutive days without rainfalls will increase. Namely, for the period 2011–2040. in the north of the country, the change in this index is around –5% both in the case of the JJA season and in the case of the annual change. The positive change in the southeastern part of the country is slightly higher for the JJA season compared to the annual change and the maximum value is about 30%. For the remaining two analyzed periods, 2041–2070. and 2071–2100, a positive change, i.e., an increase in the number of consecutive days without precipitation dominates the entire territory, with it being significantly higher for the period 2071–2100;

The number of summer days, (days when the maximum daily temperature is higher than 25 ° C), will continuously increase until the end of this century in the case of the considered scenario. Changes in the number of summer days on an annual basis for all three periods are similar to changes in the number of these days during the summer months. During the period from 2011 to 2040, more or less uniform changes can be expected throughout the territory and an increase in their number to 100%, or twice as many these days compared to their number during the period 1971-2000. For the remaining two analyzed periods, 2041–2071. and 2071–2100. the changes are more pronounced in the northern mountainous part of the country. During the period 2041–2071. most of the northern part of the country has a positive change of 300%, i.e., it can be expected that it will be about four times more these days compared to the period 1971-2000

Moreover, the number of tropical days when the maximum daily temperature is higher than 30 ° C will continue to rise until the end of this century in the case of the RCP8.5 scenario. During the period from 2011-2040. a relatively uniform change can be expected throughout the territory and an increase in their number to 100%, or twice as many these days compared to their number during the period 1971-2000, except in the northwest of the country where this change is somewhat smaller. For the remaining two analyzed periods, 2041–2071. and 2071–2100. the changes are more pronounced in the northern mountainous part of the country, similar to the case of the summer day number index. During the period 2041–2071. most of the northern part of the country has a positive change corresponding to an increase in the number of these days by about six times compared to the period 1971-2000. (change of 500%), while for the period 2071–2100. the maximum value indicates that their number can be expected to be 15 times higher than the number during the reference period. In the southeast of the country, as in the case of the number of summer days, the change in this index is the smallest in terms of relative change.

Nevertheless, the heatwaves will be mor frequent and longer. The total length and number of tropical waves will continue to grow until the end of this century in the case of the RCP8.5 scenario. During the period from 2011 to 2040, an increase in their number can be expected throughout the territory, from 200% to 400% (or 3-5 times more heat waves), as well as an increase in the duration of about 100% (on average twice as long)), in relation to their average duration during the period 1971–2000. In the coastal areas, somewhat more pronounced changes can be expected compared to those that can be seen in most of the territory. During the period 2041–2070. an increase in their number can be expected, from 400% to 700% (i.e., 5-8 times more heat waves) as well as an increase in duration from 300% to 500%, with the change being more pronounced in the southern and coastal parts of the country. In the coastal areas, somewhat more pronounced changes can be expected compared to those that can be seen in most of the territory.

The increased temperature, more frequent and prolonged heatwaves, reduction of rainfalls in some regions, and increased number of summer and tropical days will have a very negative impact on crops and livestock, increase heat stress, reduce productivity and particularly affect livestock with disturbed welfare. Moreover, increased intensive rainfalls can promote erosion and cause floods that can cause severe damage to agriculture; thus, we can conclude that in future climates agriculture will be more vulnerable than at present.

The very low adaptive capacities confirmed by low productivity even in the present climate will be a serious problem, and building the adaptive capacities have to be the highest priority in the country.

Moreover, Montenegrin agriculture is going to face difficulties due to the impact of climate change on agriculture. Even though Montenegro is a small country the relief is very diversified and there are 3 different zones, a coastal zone that is the typical Mediterranean, a middle zone with the influence of Mediterranean and mountainous climate, and a north part with continental mountainous influences. **While coastal and central zone with changing climate is going to lose suitability for agricultural production as existing in present, the north region is going to heat much faster and to change the climate too much more favorable for growing present crops. Therefore, while adverse effects will happen in the south and central zone, the north zone is going to have much better suitability for crops. The logical response will be to move crops northward and toward higher elevations and to put the crops back in more suitable conditions. But this can work only on paper. Climate suitability is only one part of the agricultural system. The problems will appear with land availability, soil suitability, terrain, relief etc. Moreover, moving crops to other locations will disturb all value chains, disconnecting suppliers from their customers, the processing industry from agricultural products, extension officers from farmers, livestock farms from fodder sources etc. However not reacting will make all regions face climate change impact. The better suitability for maize growing in the north does not mean that their traditional cropping system will benefit. Likely the existing agricultural system in the north will be disturbed similarly to the system in the south and central part.**

Livestock production will be also highly affected, heat stress is just part of the problem. There will be less fodder, less water available risk of new diseases, reduced profitability, and many other problems. Moreover, the Montenegrin traditional "katun production" will be disturbed by increased heath, possible reduction of grasses productivity, and eventual changes in floristic compositions of the pastures and natural meadows.

However, we should take into consideration that the vulnerability of the entire sector can't be evaluated with only one assessment, and this report is focusing on the general climate change impact and the specific impact on few representative crops (maize, winter wheat, potato, tomato and grape), dairy cows as representative of the livestock populations and touches upon the vulnerability of the sector beekeeping (which is a separate category and is not considered as part of the agricultural production). The capacities should be developed, and similar assessment should be conducted on a level of

municipality, which will enable a detailed assessment on location specific climate vulnerabilities and will produce a much more appropriate list of adaptation measures which will address the local problems and vulnerabilities.

6. Economic impact assessment of the climate change impact on the sector Agriculture

Methodological approach

In Montenegro, as in the region, there is no officially defined methodology on the procedure and manner of determining the damage caused by climate change, as well as the methodology for assessing future harmful economic impacts caused by climate change. The activities so far in assessing these damages are mainly based on the activities of concrete assessment of material damage, due to certain emergency events, which are a consequence of changed climate.

The task defined within the scope of this document, is to assess future adverse economic impacts caused by climate change over a longer period of time. These impacts were analyzed for four defined sectors, on which climate change may have or already have a significant impact: **agriculture, tourism, water resources and health**.

The basic premise for the analysis was that in the long run, until 2050 and 2100, ocurance of climate change will have such a negative economic impact in these sectors, which is obvious and can be directly valorized. The mode of impact in each sector is different, depending on the nature of the activity and is reflected mainly in either reduced revenue or increased costs.

In the sector of **agriculture**, two groups of effects were considered. The first group is reflected in the reduced volume of income from the sale of grain, because it is assumed that the increase in temperature in the long run will negatively affect the yield. The second group of effects involves increased costs due to increased needs for water and irrigation of agricultural land, which is caused by higher temperatures in the future. In order to gain an overview of this, for the first group of effects, it was necessary to:

- Collect appropriate statistical data on realized grain yields in the previous period;
- Perform processing and analysis of collected data, as a basis for further projections;
- Project future grain yields for the baseline scenario - “no climate change” scenario;
- Assess quantitative damage - lower grain yields, caused by climate change, in accordance with established climate scenarios;
- Analyze grain prices in Montenegro and the world and determine future unit prices, as a basis for damage assessment;
- Based on previously collected and processed data, calculate and project the economic damage caused by climate change in this sector.

For the second group of effects, within the sector of agriculture, it was necessary to:

- Collect appropriate statistical data on the level of land irrigation and water consumption for these purposes in the previous period;
- Process and analyse collected data, as a basis for further projections;
- Project the future volume of irrigation and water consumption, for the basic scenario - the scenario "without climate change";
- Assess quantitative damage - additional water consumption, caused by climate change, in accordance with established climate scenarios;
- Analyse additional electricity consumption foreseen for pumping additional water;
- Analyze electricity prices in Montenegro and in the world and determine future unit prices, as a basis for damage assessment;
- Based on previously collected and processed data, calculate and project economic damage caused by climate change on this basis, in this sector.

Defining the time frame for observation/analysis was the next important step. Climate change is a phenomenon that occurs slowly and not so noticeably, so its consequences, namely negative effects, cannot be adequately assessed for shorter periods of time (e.g. up to 20 years), which is common for different types of economic analysis. For this reason, and based on research and recommendations from numerous documents, especially the document "IPCC Special Report, Emission Scenarios" (Intergovernmental Panel on Climate Change, WMO and UNEP, 2000) it was decided to assess economic damage as a consequence of climate change for:

- ➢ The period of the near future, until 2050 (Near Future) and
- ➢ The period of the distant future, up to 2100 (Far Future).

In the scope of the further analysis, and due to the impossibility to precisely define at this moment the extent of impact on the climate which will occur in these defined periods, and therefore what negative consequences these changes will cause, it was decided to observe two scenarios - more favorable and less favorable, within each period of time. The number of scenarios can certainly be higher, but it is estimated that for the sake of clarity of the analysis, and also its objective (to determine the preliminary approximate level of considered adverse effects), this number of scenarios is sufficient.

Ideally, further analysis would imply that within each considered sector, adverse effects are quantified by defined categories of analysis, for both time frames and for both climate scenarios. Given that this is very difficult at the moment, since adequate researches are scarce, as well as data in Montenegro on it, the experiences in analysis and research in Europe and the world were considered. Data and assumptions in these sources vary, so only those which served to define the criteria for this analysis are presented below.

Within the document *"The Economic Impact of Climate Change in Montenegro"*(UNDP, 2010), the assessment of economic damage for individual sectors was performed on the basis of the following assumptions:

- For the period up to 2050, 2 scenarios: losses of 3% and 8%;
- For the period up to 2100, 2 scenarios: losses of 8% and 15%

Researches abroad have mainly focused on predicting adverse effects on the total national GDPs as a result of climate change. Thus, for example, in a document prepared by the Swiss Re Institute, *"The Economics of Climate Change: No Action not an Option"* (April 2021) the expected impact on global GDP by 2050 was presented, according to four different scenarios, as compared to the world "without climate change". Those are the following scenarios for Europe:

- Decrease of GDP of 2.8%, if the goals of the Paris Agreement are achieved (increase in temperature well below 2 ° C);
- Decrease of GDP of 7.7%, if further mitigation measures are taken (temperature increase of 2 ° C);
- Decrease of GDP of 8.1%, if some mitigation measures are taken (2.6 ° C increase in temperature);
- Decrease of GDP of 10.5%, if mitigation measures are not taken (temperature increase of 3.2 ° C).

As it can be seen, harmful effects by 2050 are estimated in the range from about 3% to approximately 10% for the period until 2050.

The third document that served as a basis for further analysis is the official document of the International Monetary Fund from 2019, *"Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis"* (International Monetary Fund, 2019). In this document, there is analysis of negative impact of climate change on GDP, by countries, grouped in relation to their geographical location and economic situation. The analysis showed that these damages, for a group of countries including Montenegro, would be the following:

- for the period up to 2050: losses of 2.18% and 3.11%;
- for the period up to 2100: losses of 6.05% and 8.25%

It is obvious that the predicted adverse effects within this document are somewhat lower than in the previous ones, which only confirms the view that their prognosis is not simple and depends on numerous input assumptions. Therefore, in order to cover the broader framework of analysis and future estimates, within this document the analysis was performed for all considered sectors with the **following scenarios**:

1. Near future, damage level by 2050 5% (Near Future 1, NF1),
2. Near Future, damage level by 2050 10% (Near Future 2, NF2),
3. Far future, damage level by 2100 10% (Far Future 1, FF1),
4. Far Future, damage level by 2100 15% (Near Future 1, FF2).

Projections of individual economic categories are made relying on certain growth rates based ither on historical data, or on the fluctuations of a certain category in the past period, or using official GDP growth rates, or certain sectoral rates or a combination of all mentioned above with appropriate estimates of sectorial experts.

In this particular case, some historical rates are not fully relevant due to the atypical 2020. This also applies to the GDP growth rate, which dropped significantly in 2020. For that reason, it was decided to follow the precautionary principle with moderate growth rates, in relation to the initial state. By sectors:

- Agriculture: 0.5% per year;
- Tourism: 1.5% per year;
- Water resources: 0.5% per year;
- Health: 1% per year.

As already mentioned, in sectors of Agriculture and Water Resources, growth rates are lower, due to real capacity, which is limitted. Significantly higher growth rates have been taken into account in the sector of tourism untli 2020, while in the Health sector the benchmark was the target number of deaths in the aforementioned "Program for adapting the health system to climate change in Montenegro for the period 2020-2022"[58]

Climate is one of the essential elements that affects agricultural production, and climate change inevitably affects its volume and quality. Assessing the economic consequences of climate change on agriculture requires comprehensive assessments of impact chain - from climate to crops and the economy.

Evidence from numerous studies and previous research has unequivocally confirmed the impact of climate change on agriculture. Agricultural production is closely linked to the climate and therefore bears, perhaps, the greatest burden of climate change. With evidence from numerous studies confirming the impact of climate change on crop yields, an increasing number of researchers have focused on the resulting economic impacts. The already negative effects of climate change on agriculture have already been confirmed, but it is also expected

[58] https://wapi.gov.me/download/6982b1d9-5fb9-40bb-b8e6-dedefd8b2ead?version=1.0

that they will increase in the future. Agricultural production accounts for a large share of the world economy, so the economic consequences of climate change cannot be ignored.

Plausible assessments of the impact of climate change on agriculture require combined use of climate models models for crop yields and economic models. The results of previous research vary due to differences in models, scenarios, and data. Climate change is changing the weather and thus having direct, biophysical effects on agricultural production. Assessing the ultimate consequences of these effects requires detailed assessments at every step in the modelling of impact chain, from climate to crops and economy.

There are different approaches used to evaluate the impact of climate change in agriculture, and within this analysis the Agro-economic approach was used. This approach combines an agronomic approach to determine the impact of climate change on crop yields, with agricultural market models to determine both price and economic gains and losses due to climate change.

Three types of estimates have been applied for this sector:

1. **Research on the impact of climate change on grain yields and revenues from their production;**
2. **Research on the impact of climate change on the yields of the most important agricultural crops (potatoes, tomatoes, grapes) and income from their production;**
3. **Examination of additional costs of water supply for irrigation of crops, which are negatively affected by climate change, in the form of reduced soil moisture and increased water requirements.**

Assessment of the impact of climate change on grain yields and revenues from their production

In order to measure the effects of climate change on the production of cereals and revenues from their sale, firstly, it is necessary to make a long-term projection (until 2100) of production in the basic scenario ("without climate change").

It is very difficult to project the quantities of planted and harvested areas from year to year, without an appropriate model that would take into account different variables (technological changes, economic development, market parameters, etc.). The existing statistical indicators, that is, data on cereal production in the previous period, served as a starting point (previously, the value of the total used agricultural land was given, as well as the share of perennial plantations and meadows). These data are shown in the following tables:

Table 16 Total agricultural land and perennial meadows and pastures in Montenegro, 2015-2020[59]

Year	Total utilized agricultural land (ha)	Perennial meadows and pastures (ha)
2015	231.405	217.633
2016	255.846	241.333
2017	256.361	241.724
2018	256.808	242.113
2019	257.470	242.718
2020	257.950	243.304

Table 17 Harvested area and yield – Wheat, 2015-2020[60]

Year	Harvested area (ha)	Yield (t/ha)	Total yield (t)
2015	736,5	2,9	2135,9
2016	747,1	3,2	2390,7
2017	766,3	3,2	2452,2
2018	768,8	3,2	2460,2
2019	770,4	2,8	2157,1
2020	735,2	3,0	2205,6

Table 18 Harvested area and yield – Maize, 2015-2020

Year	Harvested area (ha)	Yield (t/ha)	Total yield (t)
2015	629,4	4,3	2706,4
2016	628,1	4,2	2638,0
2017	641,6	4,2	2694,7
2018	645,4	4,3	2775,2
2019	639,2	4,3	2748,6
2020	610,4	4,2	2563,7

[59] Statistical Office – Monstat, Agriculture and fisheries, Structural statistics, https://www.monstat.org/eng/page.php?id=1007&pageid=59

[60] Statistical Office – Monstat, Agriculture and fisheries, production statistics, crop production, https://www.monstat.org/cg/page.php?id=62&pageid=62

Table 19 Harvested area and yield – Barley, 2015-2020[61]

Year	Harvested area (ha)	Yield (t/ha)	Total yield (t)
2015	370,1	2,6	962,3
2016	385,9	2,8	1080,5
2017	394,9	2,7	1066,2
2018	395,4	2,7	1067,6
2019	394,2	2,5	985,5
2020	327,8	2,9	950,6

Table 20 Harvested area and yield – Oats, 2015-2020[62]

Year	Harvested area (ha)	Yield (t/ha)	Total yield (t)
2015	202,7	2,7	547,3
2016	207,1	2,7	559,2
2017	209,9	2,6	545,7
2018	212,3	2,7	573,2
2019	213,9	2,8	598,9
2020	232,1	2,6	603,5

Table 21 Harvested area and yield – Ray, 2015-2020

Year	Harvested area (ha)	Yield (t/ha)	Total yield (t)
2015	178,2	1,9	338,6
2016	183,9	2,1	386,2
2017	181,7	2,3	417,9
2018	182,5	2,4	438,0
2019	165,0	2,4	396,0
2020	145,4	2,5	363,5

For the purpose of projections, the existing planted area is kept constant because it is too difficult to simulate what could happen without combining agricultural sector models. However, future technological changes have been taken into account, which will certainly

[61] Ibid

[62] Ibid

affect the increase in yield per unit area of plantations. Projections of total yields by cereal types are shown in the following table:

Table 22 Projections by type of grain (t)

Year	Wheat	Maize	Barley	Oats	Ray
2025	2.335	2.728	1.034	580	396
2030	2.394	2.797	1.060	595	406
2035	2.454	2.868	1.087	610	416
2040	2.516	2.940	1.114	625	427
2045	2.580	3.014	1.143	641	437
2050	2.645	3.091	1.171	657	448
2055	2.712	3.169	1.201	674	460
2060	2.780	3.249	1.231	691	471
2065	2.850	3.331	1.262	708	483
2070	2.922	3.415	1.294	726	496
2075	2.996	3.501	1.327	744	508
2080	3.072	3.589	1.361	763	521
2085	3.149	3.680	1.395	782	534
2090	3.229	3.773	1.430	802	548
2095	3.311	3.868	1.466	822	561
2100	3.394	3.966	1.503	843	576

After this, it was necessary to perform an expert assessment of the impact of climate change on grain production for different projected time periods, as well as for the appropriate climate scenarios. Four scenarios were considered:

1. Near Future, crop reduction by 5% by 2050 (Near Future 1, NF1),
2. Near future, crop reduction by 2050 by 10% (Near Future 2, NF2),
3. Far future, crop reduction by 10% by 2100 (Far Future 1, FF1),
4. Far Future, crop reduction by 2100 by 15% (Near Future 1, FF2),

Based on these estimates, a projection of the reduction in cereal production due to the effects of climate change is made, which is shown in the following tables:

Table 23 Projection of grain production reduction (t), NF1

Year	Wheat	Maize	Barley	Oats	Ray
2025	12	14	5	3	2
2030	34	39	15	8	6
2035	56	66	25	14	10
2040	80	94	36	20	14
2045	105	123	47	26	18
2050	132	155	59	33	22
Total	**1.820**	**2.127**	**806**	**452**	**309**

Table 24 Projection of grain production reduction (t), NF2

Year	Wheat	Maize	Barley	Oats	Ray
2025	24	28	11	6	4
2030	66	77	29	16	11
2035	111	130	49	28	19
2040	159	186	70	39	27
2045	210	245	93	52	36
2050	265	309	117	66	45
Total	**3.614**	**4.223**	**1.601**	**898**	**613**

Table 25 Projection of grain production reduction (t), FF1

Year	Wheat	Maize	Barley	Oats	Ray
2025	9	10	4	2	1

2030	24	27	10	6	4
2035	39	46	17	10	7
2040	56	65	25	14	9
2045	74	86	33	18	12
2050	92	108	41	23	16
2055	112	130	49	28	19
2060	132	154	59	33	22
2065	154	180	68	38	26
2070	177	206	78	44	30
2075	200	234	89	50	34
2080	226	264	100	56	38
2085	252	294	112	63	43
2090	280	327	124	69	47
2095	309	361	137	77	52
2100	339	397	150	84	58
Total	**11.672**	**13.638**	**5.169**	**2.899**	**1.979**

Table 26 Projection of grain production reduction (t), FF2

Year	Wheat	Maize	Barley	Oats	Ray
2025	13	15	6	3	2
2030	35	40	15	9	6
2035	58	68	26	14	10
2040	82	96	37	20	14
2045	109	127	48	27	18
2050	136	159	60	34	23
2055	165	193	73	41	28

2060	196	229	87	49	33
2065	228	267	101	57	39
2070	262	307	116	65	45
2075	298	349	132	74	51
2080	336	393	149	84	57
2085	376	440	167	93	64
2090	418	489	185	104	71
2095	463	541	205	115	78
2100	509	595	225	126	86
Total	**17.386**	**20.314**	**7.700**	**4.318**	**2.948**

The next important step is to determine the prices of cereals in the near and distant future. Predicting the prices of these crops in the future would require analysis of various factors not only in the Montenegrin agricultural sector, but also in those countries that may affect food prices in Montenegro due to imports and exports, which would be extremely complicated. For this reason, as in estimating the amount of crops, an analysis of cereal prices in the previous period was performed. Variations in crop prices over the last decade reflect variations that are sure to manifest in the future. At the moment, it was not possible to determine these variations with certainty, hence, in this document for further needs of the analysis, the average determined prices by type of grains were used, both for domestic and international prices.

Table 27 Average unit prices by type of grains

Cereals	Unit price (EUR/t)
Wheat	250
Maize	220
Barley	250
Oats	210
Ray	220

The calculation of economic damage in the agricultural sector, due to the effects of climate change, was performed on the basis of previously established data, and presented in the following tables:

Table 28 Estimate of economic damage, NF1 (EUR)

Year	Wheat	Maize	Barley	Oats	Ray	Total
2025	3.059	3.146	1.355	638	457	8.655
2030	8.401	8.638	3.721	1.753	1.254	23.767
2035	14.058	14.455	6.226	2.933	2.098	39.770
2040	20.044	20.610	8.877	4.182	2.991	56.704
2045	26.374	27.119	11.681	5.502	3.935	74.611
2050	33.063	33.997	14.643	6.898	4.933	93.534
Total	**455.113**	**467.967**	**201.569**	**94.947**	**67.908**	**1.287.504**

Table 29 Estimate of economic damage, NF2 (EUR)

Year	Wheat	Maize	Barley	Oats	Ray	Total
2025	5.992	6.161	2.654	1.250	894	16.950
2030	16.521	16.988	7.317	3.447	2.465	46.738
2035	27.762	28.546	12.296	5.792	4.142	78.537
2040	39.750	40.872	17.605	8.293	5.931	112.451
2045	52.524	54.008	23.263	10.958	7.837	148.589
2050	66.125	67.993	29.287	13.795	9.867	187.067
Total	**903.537**	**929.056**	**400.175**	**188.499**	**134.818**	**2.556.085**

Table 30 Estimate of economic damage, FF1 (EUR)

Year	Wheat	Maize	Barley	Oats	Ray	Total
2025	2.144	2.204	949	447	320	6.065
2030	5.879	6.045	2.604	1.227	877	16.632

2035	9.825	10.102	4.351	2.050	1.466	27.794
2040	13.990	14.385	6.196	2.919	2.087	39.577
2045	18.383	18.903	8.142	3.835	2.743	52.006
2050	23.016	23.666	10.194	4.802	3.434	65.111
2055	27.896	28.684	12.355	5.820	4.162	78.917
2060	33.035	33.968	14.631	6.892	4.929	93.456
2065	38.444	39.530	17.027	8.020	5.736	108.758
2070	44.134	45.381	19.547	9.207	6.585	124.854
2075	50.116	51.532	22.196	10.455	7.478	141.778
2080	56.403	57.996	24.981	11.767	8.416	159.563
2085	63.007	64.787	27.906	13.145	9.401	178.246
2090	69.941	71.916	30.977	14.591	10.436	197.862
2095	77.219	79.400	34.200	16.110	11.522	218.450
2100	84.854	87.250	37.582	17.703	12.661	240.050
Total	**2.917.889**	**3.000.302**	**1.292.328**	**608.741**	**435.382**	**8.254.642**

Table 31 Estimate of economic damage, FF2 (EUR)

Year	Wheat	Maize	Barley	Oats	Ray	Total
2025	3.146	3.235	1.393	656	469	8.901
2030	8.641	8.885	3.827	1.803	1.289	24.444
2035	14.460	14.869	6.405	3.017	2.158	40.908
2040	20.620	21.203	9.133	4.302	3.077	58.335
2045	27.136	27.902	12.018	5.661	4.049	76.766
2050	34.022	34.983	15.068	7.098	5.076	96.248
2055	41.296	42.463	18.290	8.615	6.162	116.826

2060	48.975	50.358	21.691	10.217	7.308	138.550
2065	57.077	58.689	25.279	11.908	8.517	161.469
2070	65.620	67.473	29.063	13.690	9.791	185.637
2075	74.623	76.731	33.051	15.568	11.135	211.108
2080	84.108	86.483	37.251	17.547	12.550	237.938
2085	94.093	96.751	41.674	19.630	14.040	266.188
2090	104.602	107.557	46.328	21.822	15.608	295.917
2095	115.657	118.923	51.224	24.129	17.257	327.191
2100	127.281	130.876	56.372	26.554	18.992	360.074
Total	**4.346.423**	**4.469.184**	**1.925.023**	**906.767**	**648.536**	**12.295.934**

As it can be seen, the estimated level of damage ranges from 1.3 to 2.6 million EUR in the scenarios until 2050, and in the amount of 8.3 to 12.3 million EUR in the scenarios until 2100. This amount corresponds to the share of cereal production in total agricultural production (which is not large), but it is indicative and represents the approximate amount of this damage.

Research on the impact of climate change on the yields of the most important agricultural crops (potatoes, tomatoes, grapes) and income from their production

In order to measure the effects of climate change on the production of certain agricultural crops and the income from their sale, it is first necessary to make a long-term projection (up to the year 2100) of production in the base case (without climate change).

As with cereals, it is quite difficult to project the quantities of this production from year to year without appropriate models that would take into account various input factors (technological changes, economic development, market parameters, etc.). Existing statistical indicators, i.e. data on production in the previous period, served as the basis. These data are presented in the following tables:

Table 32 Harvested area and yield - Potatoes, year 2015-2020 63

Year	Harvested area	Yield	Total yield
	(ha)	(t/ha)	(t)
2015	1.616,4	16,8	27.193,4
2016	1.612,7	18,6	29.916,6
2017	1.616,0	17,0	27.500,6
2018	1.618,5	16,1	26.098,1
2019	1.623,8	16,4	26.557,1
2020	1.707,5	17,3	29.460,5

Table 33 Planted area and yield - Tomato, year 2015-2020

Year	Harvested	Yield	Total yield
	area (ha)	(t/ha)	(t)
2015	114,3	34,4	3.935,8
2016	139,6	32,0	4.464,1
2017	143,8	33,2	4.767,7
2018	146,2	33,3	4.865,9
2019	146,1	30,4	4.444,1
2020	139,7	32,7	4.568,0

Table 34 Area and yield - Grapes, year 2015-2020

Year	Harvested	Yield	Total yield
	area (ha)	(t/ha)	(t)
2015	2.708,0	8,8	23.085,6
2016	2.860,4	10,4	28.925,4
2017	2.850,0	7,9	22.201,9
2018	2.837,9	8,8	24.440,6
2019	2.880,0	7,4	21.865,0
2020	2.888,0	7,5	22.711,1

In the projections, the existing planted area is kept constant because it is too difficult to simulate what could happen without combining the agricultural sector model. Nevertheless, future technological changes were taken into account, which will certainly affect the increase

[63] Statistical office of Montenegro, Agriculture and fishing, Crop production

https://www.monstat.org/eng/page.php?id=62&pageid=62

in yield per unit of planting area. Projections of total yields by types of agricultural crops are shown in the following table:

Table 35 Projections of yields by types of agricultural crops (t)

Year	Potato	Tomato	Grapes
2025	28.207	4.576	24.231
2030	28.919	4.691	24.843
2035	29.649	4.810	25.471
2040	30.398	4.931	26.114
2045	31.165	5.056	26.773
2050	31.952	5.183	27.449
2055	32.759	5.314	28.142
2060	33.586	5.448	28.853
2065	34.434	5.586	29.582
2070	35.304	5.727	30.329
2075	36.195	5.871	31.094
2080	37.109	6.020	31.880
2085	38.047	6.172	32.685
2090	39.007	6.328	33.510
2095	39.992	6.487	34.356
2100	41.002	6.651	35.224

After that, it is necessary to carry out an expert assessment of the impact of climate change on the production of agricultural crops for different projected time periods, as well as for appropriate climate scenarios.

Four scenarios were considered:

1. Near future, crop reduction by 2050 by 5% (Near Future 1, NF1),
2. Near future, crop reduction by 2050 by 10% (Near Future 2, NF2),
3. Far future, crop reduction by 2100 by 10% (Far Future 1, FF1),

4. Far future, crop reduction by 2100 by 15% (Near Future 1, FF2),

On the basis of these estimates, a reduction in the production of the considered crops due to the effects of climate change is projected, and it is shown in the following tables:

Table 36 Projection of reduction in production of agricultural crops (t), NF1

Year	Potato	Tomato	Grapes
2025	148	24	127
2030	406	66	349
2035	679	110	584
2040	969	157	832
2045	1.274	207	1.095
2050	1.598	259	1.372
Total	**21.991**	**3.567**	**18.892**

Table 37 Projection of reduction in production of agricultural crops (t), NF2

Year	Potato	Tomato	Grapes
2025	290	47	249
2030	798	130	686
2035	1.341	218	1.152
2040	1.921	312	1.650
2045	2.538	412	2.180
2050	3.195	518	2.745
Total	**43.660**	**7.082**	**37.507**

Table 38 Projection of reduction in production of agricultural crops (t), FF1

Year	Potato	Tomato	Grapes
2025	104	17	89
2030	284	46	244

2035	475	77	408
2040	676	110	581
2045	888	144	763
2050	1.112	180	955
2055	1.348	219	1.158
2060	1.596	259	1.371
2065	1.858	301	1.596
2070	2.133	346	1.832
2075	2.422	393	2.080
2080	2.725	442	2.341
2085	3.045	494	2.615
2090	3.380	548	2.903
2095	3.731	605	3.205
2100	4.100	665	3.522
Total	**140.995**	**22.872**	**121.124**

Table 39 Projection of reduction in production of agricultural crops (t), FF2

Year	Potato	Tomato	Grapes
2025	152	25	131
2030	418	68	359
2035	699	113	600
2040	996	162	856
2045	1.311	213	1.126
2050	1.644	267	1.412
2055	1.995	324	1.714
2060	2.367	384	2.033

2065	2.758	447	2.369
2070	3.171	514	2.724
2075	3.606	585	3.098
2080	4.064	659	3.491
2085	4.547	738	3.906
2090	5.054	820	4.342
2095	5.589	907	4.801
2100	6.150	998	5.284
Total	**210.023**	**34.069**	**180.424**

The next important step in the analysis is determining the prices of analyzed agricultural crops in the near and distant future. As with cereals, predicting the prices of these crops in the future would require the analysis of various factors, not only in the Montenegrin agricultural sector, but also in those countries that can affect food prices in Montenegro due to imports and exports, which would be extremely complicated. For these reasons, as well as with the assessment of crop production, an analysis of prices in the previous period was carried out. Variations in crop prices over the past decade reflect variations that are sure to manifest in the future. At this moment, it is not possible to determine these variations with certainty, so for the purposes of further analysis within this document, the average established prices by types of agricultural crops were used.

Table 40 Average unit prices by types of agricultural crops

Agricultural crops	Unit prices (EUR/t)
Potato	225
Tomato	550
Grapes	700

Based on the previously determined data, the calculation of economic damages in the agricultural sector, due to the effects of climate change, was performed, and it is shown in the following tables:

Table 41 Calculation of economic damages, NF1 (EUR)

Year	Potato	Tomato	Grapes	Total

2025	33.263	13.190	88.901	135.354
2030	91.340	36.219	244.120	371.678
2035	152.841	60.606	408.493	621.939
2040	217.921	86.412	582.430	886.764
2045	286.740	113.700	766.360	1.166.801
2050	359.464	142.537	960.725	1.462.726
Total	**4.948.069**	**1.962.043**	**13.224.521**	**20.134.633**

Table 42 Calculation of economic damages, NF2 (EUR)

Year	Potato	Tomato	Grapes	Total
2025	65.141	25.830	174.100	265.072
2030	179.623	71.225	480.072	730.920
2035	301.831	119.684	806.691	1.228.206
2040	432.166	171.366	1.155.035	1.758.567
2045	571.052	226.437	1.526.229	2.323.717
2050	718.928	285.074	1.921.451	2.925.453
Total	**9.823.417**	**3.895.249**	**26.254.683**	**39.973.349**

Table 43 Calculation of economic damages, FF1 (EUR)

Year	Potato	Tomato	Grapes	Total
2025	23.308	9.242	62.293	94.843
2030	63.918	25.345	170.831	260.094
2035	106.816	42.355	285.483	434.654
2040	152.099	60.311	406.510	618.920
2045	199.869	79.253	534.181	813.303
2050	250.229	99.223	668.779	1.018.231

2055	303.291	120.263	810.595	1.234.149
2060	359.167	142.419	959.931	1.461.517
2065	417.973	165.738	1.117.102	1.700.813
2070	479.834	190.267	1.282.434	1.952.534
2075	544.874	216.057	1.456.264	2.217.195
2080	613.225	243.160	1.638.945	2.495.330
2085	685.024	271.631	1.830.839	2.787.494
2090	760.412	301.524	2.032.325	3.094.262
2095	839.535	332.898	2.243.795	3.416.229
2100	922.546	365.814	2.465.655	3.754.016
Total	**31.723.828**	**12.579.352**	**84.787.098**	**129.090.278**

Table 44 Calculation of economic damages, FF2 (EUR)

Year	Potato	Tomato	Grapes	Total
2025	34.207	13.564	91.424	139.195
2030	93.943	37.251	251.078	382.272
2035	157.217	62.341	420.188	639.746
2040	224.189	88.897	599.181	912.266
2045	295.024	116.985	788.499	1.200.507
2050	369.894	146.673	988.602	1.505.170
2055	448.980	178.033	1.199.972	1.826.984
2060	532.467	211.138	1.423.106	2.166.710
2065	620.550	246.065	1.658.522	2.525.137
2070	713.431	282.895	1.906.761	2.903.086
2075	811.319	321.710	2.168.383	3.301.412
2080	914.433	362.597	2.443.971	3.721.001

2085	1.022.999	405.647	2.734.132	4.162.778
2090	1.137.254	450.952	3.039.497	4.627.702
2095	1.257.442	498.610	3.360.720	5.116.772
2100	1.383.820	548.722	3.698.483	5.631.024
Total	**47.255.119**	**18.737.927**	**126.297.005**	**192.290.051**

As can be seen from the estimates presented above, the level of economic damages ranges from 20 to 40 million EUR in scenarios up to 2050, that is, in the amount of 130 to nearly 200 million EUR in scenarios up to 2100. We note that the mentioned amounts are quite significant, especially for the agricultural sector, and indicate that the potential damages due to climate change in this area are not negligible.

Assessment of additional costs of irrigation water supply

In the previous period, the impact of climate change on soil moisture and crop needs for water has undoubtedly been proven. It is clear that as temperatures rise and precipitation decreases, there will be less water for growing crops. The loss of water in the soil will result in the need to supply additional water for irrigation in order to meet the increased water needs for crops. This increased need for irrigation water can be translated into economic impact, if the additional cost of water supply is taken into account.

In order to provide the initial data for the analysis, the identification of the area of irrigated land was performed, as well as the estimated amount of water used for these purposes:

Table 45 Irrigated land area and irrigation water used

Description	Amount
Irrigated land area (ha)	2,364
Irrigation water used (000 m3)	6,620

Based on these data, a projection of the irrigated land area was made, as well as the estimated amounts of water that will be used for these purposes, in the basic case ("without climate change"). The projections were made taking into account the slight increase in the area of land that will have the possibility of irrigation, as a consequence of the development of agriculture, i.e. technological progress and the overall development of the economy and society. These projections are shown in the following table:

Table 46 Projection of irrigated land area and used irrigation water

Year	Used water (000 m3)	Land area (ha)
2025	6,720	2,400
2030	6,889	2,460
2035	7,063	2,522
2040	7,242	2,586
2045	7,425	2,651
2050	7,612	2,718
2055	7,804	2,787
2060	8,001	2,857
2065	8,203	2,929
2070	8,411	3,003
2075	8,623	3,079
2080	8,841	3,157
2085	9,064	3,237
2090	9,293	3,318
2095	9,528	3,402
2100	9,768	3,488

After that, an assessment of the impact of climate change on the increase in water consumption for irrigation, for the projected time periods, as well as for the corresponding climate scenarios was performed. Four scenarios were considered:

- Near future, increase in water consumption for irrigation by 2050 by 5% (NF1),
- Near future, increase in water consumption for irrigation by 2050 by 10% (NF2),
- Far future, increase in water consumption for irrigation by 2100 by 10% (FF1),
- Far Future, increase in water consumption for irrigation by 2100 by 15% (FF2),

The projection of the calculation of additional water consumption for irrigation, according to the scenarios, is shown in the following table:

Table 47 Projection of additional water consumption for irrigation (000 m3)

Year	NF1	NF2	FF1	FF2
2025	35	69	25	36
2030	97	190	68	99
2035	162	320	113	166
2040	231	458	161	237
2045	304	605	212	312
2050	381	761	265	392
2055			321	475
2060			380	564
2065			443	657
2070			508	755
2075			577	859
2080			649	968
2085			725	1,083
2090			805	1,204
2095			889	1,331
2100			977	1,465
Total	**5,239**	**10,401**	**33,590**	**50,035**

The basic and main cost of production and distribution of water for irrigation of agricultural land is the cost of electricity. An engineering formula was used to calculate the required electricity, which shows how much electricity is needed to distribute a certain amount of water. Adopted value is that 0.638 kWh of electricity is required for production, i.e. pumping of 1 m3 of irrigation water, that is 638 kWh required for pumping 1000 m3 of water, so this value will be used in further calculations.

The projection of additional electricity consumption for pumping irrigation water is shown in the following table:

Table 48 Projection of additional electricity consumption (kWh)

Year	NF1	NF2	FF1	FF2
2025	22,470	44,005	15,745	23,108
2030	61,702	121,340	43,178	63,461
2035	103,248	203,895	72,157	106,205
2040	147,212	291,940	102,747	151,446
2045	193,701	385,761	135,017	199,297
2050	242,828	485,656	169,037	249,874
2055			204,882	303,298
2060			242,627	359,696
2065			282,353	419,199
2070			324,141	481,943
2075			368,078	548,069
2080			414,251	617,725
2085			462,753	691,065
2090			513,680	768,247
2095			567,130	849,437
2100			623,206	934,809
Total	**3,342,559**	**6,635,992**	**21,430,331**	**31,922,151**

The next important step is to determine the price of electricity per kWh in Montenegro. According to the official Eurostat data, the price of electricity in Montenegro is 0.098 EUR per kWh, which is more than twice lower than the average in EU member states (0.22 EUR per kWh). Electricity prices in the countries of the region are higher in Slovenia and Croatia (0.17 and 0.13 EUR per kWh, respectively), while they are slightly lower in Serbia and Bosnia and Herzegovina (0.08 and 0.09 EUR per kWh, respectively). The highest electricity prices in Europe are in Germany and Denmark, with over 0.3 EUR per kWh. It should be noted that electricity prices in the countries of the region are still to some extent a social rather than a market category, so it is realistic to expect their growth in the long run. For this reason, the assessment of economic damages of additional electricity consumption for pumping water for land irrigation was done with 3 variants of the unit price of electricity: existing - 0.1 EUR per kWh, as well as for variants with moderate (0.15 EUR per kWh) and a more significant (0.2 EUR per kWh) price correction.In the further observation period, prices were increased in accordance with the projected growth rates from the document "World Energy Outlook" 2021.

2020 – 2030	2030 – 2050
2.3%	1.5%

Taking into account that in this document growth rates are presented until 2050, covering the near future scenario, the growth rate used for the distant future scenario, until 2100, was calculated in accordance with the trend from the previous period.

The following tables show projections of the economic damage of additional irrigation water consumption.

Table 49 Projection of economic damages of additional consumption of irrigation (price of electricity 0,1 EUR/kWh)

Year	NF1	NF2	FF1	FF2
2025	2,352	4,605	1,648	2,418
2030	7,235	14,228	5,063	7,441
2035	13,042	25,755	9,115	13,415
2040	20,032	39,727	13,982	20,609
2045	28,396	56,551	19,793	29,216
2050	38,349	76,697	26,695	39,461
2055			34,856	51,600
2060			44,468	65,925
2065			55,748	82,768
2070			68,945	102,510
2075			84,341	125,585
2080			102,257	152,485

2085			123,058	183,772
2090			147,158	220,086
2095			175,027	262,152
2100			207,197	310,796
Total	**465,147**	**923,966**	**5,167,970**	**7,707,841**

Table 50 Projection of economic damages of additional consumption of irrigation (price of electricity 0,15 EUR/kWh)

Year	NF1	NF2	FF1	FF2
2025	3,527	6,908	2,472	3,627
2030	10,852	21,342	7,594	11,162
2035	19,563	38,633	13,672	20,123
2040	30,049	59,590	20,973	30,913
2045	42,593	84,826	29,689	43,824
2050	57,523	115,046	40,043	59,192
2055			52,285	77,400
2060			66,702	98,887
2065			83,623	124,152
2070			103,418	153,765
2075			126,512	188,377
2080			153,386	228,727
2085			184,588	275,659
2090			220,737	330,129
2095			262,540	393,228
2100			310,796	466,194

Total	697,721	1,385,949	7,751,955	11,561,762

Table 51 Projection of economic damages of additional consumption of irrigation (price of electricity 0,2 EUR/kWh)

Year	NF1	NF2	FF1	FF2
2025	4,703	9,210	3,295	4,837
2030	14,470	28,455	10,126	14,882
2035	26,084	51,511	18,229	26,831
2040	40,065	79,454	27,963	41,217
2045	56,791	113,102	39,586	58,432
2050	76,697	153,394	53,390	78,923
2055			69,713	103,200
2060			88,936	131,849
2065			111,497	165,536
2070			137,891	205,020
2075			168,683	251,169
2080			204,515	304,970
2085			246,117	367,545
2090			294,316	440,172
2095			350,054	524,304
2100			414,394	621,592
Total	**930,295**	**1,847,932**	**10,335,941**	**15,415,682**

As it can be seen from the previous tables, the total amount of economic damage on this basis, up to 2100. could range from around 5.2 to 7.7 million EUR for lower electricity prices, while in the case of higher and more realistic prices of electricity in the future, the level of these damages could be up to about 15.5 million EUR.

7. Priority actions that address climate-driven vulnerabilities and gender disaggregated impacts

Adaptation options and measures are something that should be carefully elaborated and tested in the national environment, and farmers should be informed on optimal adaptation practices they should use in a given situation. Clearly, late spring frost, summer drought, and new pests required totally different solutions, therefore different adaptation practices should be applied. Therefore, serious research activities, experimental fields, and plots for testing and spreading the adaptation measures and training programs for agricultural operators should be conducted. The best solution will be to establish the Center for climate change research, technology transfer, and training in the frame of the existing institutions with research capacities in climate change in agriculture.

The first adaptation option for Montenegro will be building the adaptive capacities on the individual, institutional, and system levels in order to create a more resilient agricultural system in the country. Capacity building should not be an awareness raising, the number of stakeholders clearly know what climate change is. They need to understand the scale of the problem, links between climate, agro-climate, cropping practices, management, and market, and to be ready to implement adaptation practices. Moreover, this process has to be accompanied by the process for support and investment in adaptation practices.

The problem of data transparency is evident, and all datasets related to climate, climate change, and agriculture should be considered open data and should be available for download for all interested parties. Most of the data available in the country and hidden from the public are generated by public money generated by the taxpayers and should be transparent and readily available. In the present situation data available only for data-holders is not sustainable and limits the development of the scientific base, research, innovations, technology development, vulnerability assessment, and adaptation designing and planning in climate change to a very low level of development. Moreover, it is necessary to improve soil monitoring, particularly soil fertility, soil organic matter, and soil erosion. The capacity building of the agro-meteorological services is also among the highest priorities. Also, strengthens the capacities of the bodies responsible for phytosanitary and animal health to monitor, map and manage new pests and diseases.

Despite soft measures related to the capacity building described above, there is a number of technical measures suitable for Montenegrin agriculture. Increasing the area under irrigation is an expensive but efficient method to eliminate the negative effects of the pronounced droughts.

Moreover, a number of measures have been already tested in the region and have been characterized as the potential for further elaboration. These can be a good starting point, but careful evaluation, testing, and selection are required. Some of these measures are:

- Use of safety nets (for hail and UV rays) in orchards
- Use of drought tolerant rootstocks in apples, cherries, and sour cherries as a measure against soil water shortage
- Changes in the planting depth of apple and cherry seedlings
- Application of different materials (Trichoderma, zeolite, hydrogel) as a measure for soil water conservation
- Using pruning techniques to reduce sunburn in orchards
- Use of specific protective materials to reduce sunburn in orchards
- Mulching the space in the rows in the orchards
- Utilization of the impact of the application T the cutting system in vineyards
- Utilizing the impact of UV protection networks in vineyards
- Application of calcium carbonate in vineyards
- Application of Trichoderma harzianum in vegetable production
- Use of UV protection nets in vegetable production
- Application of plastic bags filled with soil mixture in vegetable production
- Application of determining the time and the amount of irrigation based on meteorological data from installed automatic meteorological stations
- Application of drip irrigation and fertigation, as well as conservation of water in the soil.
- Application of biochar
- Photovoltaic irrigation
- Growing cover crops

The dire effects of climate change on the survival of the bees reveal the urgent need to conserve these important insects. It is important to protect and manage bee-friendly habitats like coastal areas, grasslands, brownfield sites, farmlands, saltmarshes, and sea walls among others. Engaging in the protection of these habitats will result in increased populations of the bees and in turn higher levels of pollination leading to minimized food shortage. Another method that may be applied to protect bee habitats is by implementing environmental legislation intended to preserve areas where bees live.

However, the increased adaptive capacity among beekeepers is one of the most important steps to successfully adapting apiculture in the country to climate change. Moreover, beekeepers cannot be successful without increasing awareness and capacities among farmers in the country. Farmers need to avoid harmful pesticides, herbicides, and fertilizers that are harmful to the bees' lives and may keep bees away from plants. One of the most harmful chemicals to bees is those of the neonicotinoid family. Instead, farmers should make use of beneficial insects such as ladybugs and praying mantises on their farms[64]. Essentially, farmers should shift their farming methods from the current prevalent conventional agriculture to sustainable farming that utilizes organic fertilizers and not the inorganic fertilizers that are harmful to the bees.

For the successful adaptation, the participation of the whole society is required. The citizens have to be aware of the importance of the honeybees, their environmental services, and their important role as pollinators of the majority of agricultural crops and native vegetation. The citizens have to become bee-friendly, protect bees' habitats, reduce the use of insecticides and other bee harmful materials, and take measures to increase the presence of the wild bees in their surroundings through the popular measures of establishing zones for bee living (bee hotels), etc.

Finally, climate change will shift the balance between the honeybee, its plant environment, and its diseases. The honeybee has shown a great capacity to colonize widely diverse environments and its genetic variability should enable it to adapt to such climate change. However, the fear is that climate-induced stress will compound the various factors already endangering the honeybees in certain regions. If humans modify the honeybee's environment, they also have a duty to take conservation measures to prevent the loss of this rich genetic diversity of bees. To understand the factors favoring the extinction of honeybees, it will be necessary to conduct fundamental research aimed at ascertaining the causes of mortality, as well as the effect of human-induced environmental change. Environmental impact studies in the field, as well as the use of modern genomics methods made possible by the recent sequencing of the bee genome, are expected to play a prominent role in discovering the vital stress factors for these species.

Therefore, Montenegro should start building the national capacities for conducting research on the behavior, genomic and environmental changes response to their local breeds of Kranjska bees. The geographic and climate diversity in Montenegro offers a favorable environment for research in different climate zones, different altitudes, and different thermal and rainfall regimes within a small distance. There is the probability that some Kranjska bee strains modify their behavior to the local environment they were bred in and can be a valuable genetic basis for further research and adaptation to climate change.

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[64] https://www.worldatlas.com/articles/how-does-climate-change-affect-bees.html

Moreover, it is necessary to start building the knowledge base that will be a source for all further research as well as fundamental tools for the development and planning of evidence-based adaptation practices that will help beekeepers to continue with their activities in future period with expected climate change.

- More specific actions that address climate-driven vulnerabilities and highlighting gender disaggregated impacts are as following (financial, communication, consultative, inclusive, affirmative, etc.) to be targeted upon the gendered differences in the agricultural sector:

- **Gender responsive coherence, governance and operational procedures in the agriculture sector:** Development of institutional structure (in a form of procedures) for sex-disaggregated data collection on policy, program, project level in the sector in order to identify gender gaps in in the needs as well as the level of inequality in the access to adaptation services and resources;
- **Creation of the set of gender-sensitive indicators** based on the existing practices on collecting sex-disaggregated data upgraded with the international sets of gender indicators (SDGs);
- **Capacity building** on the methods and instruments for collecting sex-disaggregated data, as well as monitoring and reporting through design of gender indicators.
- **Monitoring and reporting**: Development of institutional structure (in a form of procedures) for monitoring progress on gender equality and women's empowerment and tracking gender-differentiated results.
- **Gender responsive gender policies** in the sector agriculture:
    - targeted towards small scale and subsistence farming in the low-income context due to the fact that are mostly presented by women, and women who are self-employed in agriculture tend to have smaller holdings and lower productivity, lacking access to the financial help, infrastructure markets and other services which are boosting agricultural productivity;
    - unpaid workers on family farms and paid or unpaid workers on other farms and agricultural enterprises (dominated by women);
    - women involved in growing crops and nurturing livestock for their own and commercial needs;
    - men (dominating the ownership structure) in the community-based adaptation activities in regard to access to resources for sustainable food production, irrigation services and clean water sources);
    - women owners of agricultural holdings to strengthen women's access to resources for sustainable food production, renewable energy, and clean water sources;
    - women and men (owners of agricultural holdings, managers of business entities, holders of individual agricultural holdings, Unpaid family workers) targeted for increased resilience to deal with climate changes (e.g., use of climate-resilient crops and farming techniques, improved land management,

clean technologies, increased knowledge and strengthened networks on climate change issues[65];

- women and men (owners of agricultural holdings, managers of business entities, holders of individual agricultural holdings, unpaid family workers) trained in sustainable production technologies, soil and water conservation, pest and disease management, animal diseases, and basic veterinary services;
- Increase of women`s participation in the agricultural management associations;
- Supportive actions for women and men labor force in the agriculture holdings in the age group 65+;
- Training, educative, supporting actions for women workers in family agricultural farms in the category “without education” and other groups with lower education.

[65] https://www.researchgate.net/figure/Conceptual-framework_fig1_321765630

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