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THIRD NATIONAL COMMUNICATION ON CLIMATE CHANGE

AGRICULTURE AND CLIMATE CHANGE

VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

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AGRICULTURE AND THE CHALLENGE OF CLIMATE CHANGE

This publication summarizes key findings from an assessment of the vulnerability of agriculture to climate change and possible adaption measures and strategies.

This assessment was made as part of the Republic of Macedonia's Third National Communication on Climate Change to the United Nations Framework Convention on Climate Change by the Ministry of Environment and Physical Planning with support from the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF).

The full report is available at:
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The importance of the agriculture sector

The livelihoods and wellbeing of more than half the population of the Republic of Macedonia are directly dependent on the agricultural sector. In rural areas with high levels of unemployment, this proportion is even higher.

Official figures show that agriculture provides employment for 36% of the total workforce. The actual figure is much higher, however, since small family farms are the predominant type of farming and the main form of labour on smallholdings is informal family employment. Eighty per cent of agricultural land is farmed in the form of smallholdings with an average size of 2.8 hectares and, according to the latest census data, there are more than 192,000 family farms in the country.

Official statistics suggest the total contribution of agriculture to GDP is around 16 per cent. Again, the actual contribution is significantly higher, since these figures take into account only a fraction of the value of the agricultural output of smallholders who sell their products.

In addition to the importance of agriculture for farmers and for the economy, a sustainable agriculture sector is a vital aspect of ensuring the country's future food security. Global population growth and climate change have made food security a key priority for all governments. A coordinated and multi-sectoral approach will thus be needed to ensure the sustainability of the agriculture sector and its resilience to the challenge of climate change.

Key characteristics of the country's agriculture & climate

The Republic of Macedonia has diverse agricultural resources, with the capacity to produce many continental and Mediterranean crops and a range of livestock products. Cropland and pastures occupy about half of the surface area of the country, with forests covering another 37 per cent.

Wheat is the major annual crop grown, with smaller areas used for barley and maize and a variety of vegetable crops. Grapes are the main perennial crop, occupying close to 25,000 hectares, with wine being second only to tobacco in terms of export value. Although the area currently occupied by fruit and nut trees is smaller, there is potential to expand this area in the future.

Only a small proportion of the country's crop production less than ten per cent makes use of irrigation, while the majority of crops are rain-fed. This leads to significant changes in the crop mix and the area planted each year, as well as in the size of crop yields, since rain-fed crops depend greatly on the timing and quantity of rainfall.

The country has a highly diverse climate due to a combination of continental and Mediterranean influences and the complex geography of valleys and mountains. The climate ranges from Alpine in the west and northwest of the country to Mediterranean in the southern districts of the River Vardar valley and is characterized by cold winters, hot summers and a highly variable precipitation regime. The various microclimates of the country have produced a highly diverse agricultural sector with a large variety of crops grown.

Alternating periods of long drought and high intensity rainfall are a common feature of the climate. This oscillation in climate, when combined with poor land management, results in soil erosion and land degradation and creates a challenging environment for the agricultural sector, particularly for farmers of rain-fed crops.

Annual mean temperatures range from approximately 8°C in the northwest regions of the country to 15°C in central areas. Precipitation generally increases from east to west across the country, with annual precipitation ranging from about 400 mm in the south-eastern and central districts to over 1,000 mm in the mountain areas bordering Albania and Kosovo.

Although there is considerable inter-annual variability, general historical trends indicate that the overall average temperature across the country has increased moderately by approximately 0.2°C while precipitation has decreased significantly by approximately 100 mm.

With the exception of the western parts of the country, water deficiencies occur during the summer season and result in significant moisture stress for summer and annual crops. In an average year, evapotranspiration is higher than rainfall, resulting in crop-water deficits of approximately 250mm in western areas and 450mm in eastern areas.

Given the critical importance of agriculture for the country's population and economy, combined with the dependence of crop yields on changes in the weather and their vulnerability to extreme weather events such as droughts and floods, it is clearly a matter of urgency for the country to assess and adapt the agriculture sector to the effects of climate change.

EROSION & LAND DEGRADATION

According to research undertaken in 1993, over 95 per cent of the total area of the country is affected by erosion, making it one of the most vulnerable in the Balkans to land degradation. The main causes of this widespread erosion include the country's mountainous landscape, unsustainable agricultural practices, and climatic variability with intense rainfalls and aridity.

Water erosion is the dominant type of erosion, with intense and concentrated rainfalls causing landslides, soil erosion and floods. Approximately 17 million cubic metres of arable soil are lost every year, incurring significant costs. Much of this soil ends up in natural lakes and reservoirs.

The major cause of soil degradation in rural areas is that of unsustainable farming practices, especially the use of inefficient irrigation schemes, the overuse of chemical fertilizers and pesticides, and mining operations.

Some thirty to eighty thousand hectares of irrigated agricultural land are vulnerable to salinization and land degradation.

Forest fires and illegal logging are also significant causes of land degradation.

Although the abandonment of some agricultural areas has helped reduce erosion, in some mountainous areas the lack of maintenance of anti-erosion terraces may actually have increased erosion.

Much of the soil in urban and industrial areas is contaminated with heavy metals and organic chemicals.

Agriculture and the Challenge of Climate Change

The latest findings of the Intergovernmental Panel on Climate Change (IPCC) suggest that crop yields around the world will decline by up to 2% per decade for the rest of the century. The 2014 IPCC report warns that climate change poses "a significant risk to food security, even with adaptation" if the world warms up by 4°C towards the end of this century. A rise of 2°C above average temperature levels of the twentieth century, says the report, will significantly reduce yields for maize, rice and wheat in the period up to 2050. The increased frequency of both droughts and floods is expected to adversely affect all agricultural production all over the world. All aspects of food security will be impacted by climate change, the report concludes, although some crop yields are likely to increase at higher latitudes under some scenarios of global average temperature increase, depending on the crop.

According to recent research, this country is expected to be amongst the first to experience warmer summers with less rain but with more intense rainfall and an increased number of storms and hail, prolonged heatwaves and more severe droughts and floods.

The negative effects of climate change are set to have a greater impact on agriculture than any other sector in the country, significantly reducing the yields of most crops. Already in 2007/2008 and 2011/2012, long dry periods and heatwaves led to significant losses in agricultural output.

Analysis of different climate change scenarios for the country show that the mean annual temperature will increase by 1.0°C by 2025 and 1.9°C by 2050, while mean precipitation is projected to decline by 3% and 5% in the same time periods, meaning a significant increase in aridity.

The impact of climate change is expected to vary significantly according to season and area. The greatest warming is projected to occur in the mountainous north-western region of the country, where only minimal reductions in precipitation are projected by 2050. The south-eastern and central regions of the country are projected to warm at a slightly slower pace, although precipitation will decline at a greater rate in the second half of the century. In the south-eastern region, a 19% decrease in summer precipitation and a 6° increase in temperature is projected to occur by 2100. Such extreme changes in temperature and precipitation will place tremendous strain on agricultural production, thus highlighting the importance of adaptation to the negative impact of climate change.

Additional regional climate modelling and/or statistical downscaling is needed to further explore local changes within the country, as it can be expected that the complex relief of the country will lead to significant local modifications of the projected national average changes.

THE CAPACITY OF THE AGRICULTURE SECTOR TO ADAPT TO CLIMATE CHANGE

The country's agriculture sector and therefore the wellbeing of the rural population is especially vulnerable because of a number of factors that limit its capacity for adaptation, including the following impediments:

Agriculture is mostly carried out by small-scale primary producers. Such small-scale farmers typically generate low annual incomes, which limits their ability to implement adaptation measures.

The small size of most agricultural plots prevents the effective implementation of adaptive measures.

Farmers receive insufficient financial support to cope with the negative impacts of climate change.

There is a low level of awareness about the effects of climate change among the key players in the agriculture sector.

There is weak networking and insufficient cooperation between scientific institutions and farmer associations in implementing know-how.

There is inadequate dissemination of research results and insufficient application of modern technologies of agricultural production.

There is insufficient experience in the implementation of modern approaches for assessing and predicting the impact of climate trends.

Agriculture in the Third National Communication on Climate Change

The main aim of the Third National Communication on Climate Change project, jointly produced by the Ministry of Environment and Physical Planning and UNDP, was to strengthen the information base and the analytical and institutional capacity of key national institutions to integrate climate change priorities into country development strategies and relevant sector programmes. A special emphasis was thus placed on expanding and upgrading the analyses already conducted at national level.

The project carried out the country's first integrated cross-sectoral assessment of vulnerability and adaptation to climate change, especially of the relations between water resources, agriculture, health and disaster risk reduction in the South-Eastern planning region.

Together with the Ministry of Education, the Third National Communication project office established close cooperation with the Joint Research Centre in Italy. The Joint Research Centre has developed an innovative Biophysical Model Application (BioMA) that enables the development of simulations. UNDP made use of this data to assess the vulnerability of agriculture in the South-East Planning Region.

The South-East Planning Region was selected as the focus of this assessment of the vulnerability of the agriculture sector and of alternative adaptation strategies because this region has been identified as one of the most vulnerable to the negative impact of climate change.

The project assessed the vulnerability to climate change of three crops-wheat, maize and sunflower—as well as conducting separate research into viticulture. There are several reasons why wheat, maize and sunflower were selected for the vulnerability assessment: winter wheat is mainly rain-fed, and maize and sunflower are both rain-fed and irrigated crops. The maize crop is sensitive to water availability. Winter wheat consumes less water but is sensitive to water stress. In addition, winter wheat and maize respond differently to increases in atmospheric CO_2.

A number of possible adaptation measures-such as forms of irrigation, different planting dates and depth, etc.- were assessed for each crop, and the economic feasibility of each adaptation was calculated to identify the most appropriate and viable solutions for adapting to the challenge of climate change.

Two process-based models were used - ClimIndices and CropSyst - allowing for the simulation of crop-soil interactions affected by weather and agricultural management. The ClimIndices model was used to assess the vulnerability of the South-East Planning Region and CropSyst was used to assess the effectiveness of alternative adaptation strategies.

An important component of the Third National Communication is a study undertaken with UNDP support on the impact of climate change on grapes and wine production. A number of simulations based on climate models were elaborated to assess the vulnerability of the country's important wine-producing sector and to explore potential adaptation measures for viticulture.

KEY FACTORS INFLUENCING AGRICULTURAL PRODUCTION

Detailed analysis was made of the key factors with a direct influence on agricultural production, including temperature, rainfall, evapotranspiration and the length of the growing season.

Air temperature & the growing season

Air temperature is a significant basic indicator for assessing the intensity of climate change in a certain area, as well as an elementary parameter for the calculation of other indicators such as the start and end of the growing season, the vegetation period, and for the calculation of aridity.

Analysis of the south-east region shows a progressive increase from 2.00–2.43 °C in average air temperature in all sub localities and for the region as a whole. These predicted increases in air temperature are in line with the newly elaborated climate scenarios for the country, which project a rise in air temperatures by 2050 of 2°C.

The negative influence of average air temperatures on agricultural production largely depends on other environmental conditions (rainfalls, evapotranspiration, dryness, etc.). For this reason, the extent of negative influences from increased air temperatures will vary in different regions of the country.

Temperatures in the growing season are very important for crop development. Each crop needs specific temperatures at each stage of their development. Any significant change in growing season temperatures will thus require a certain shift of crop growing stages, meaning that some growing stages might occur earlier or later. This indicator is closely connected with Growing Degree Days.

An increase in mean air temperatures and the number of growing degree days will lead to an earlier start of the growing season and higher evapotranspiration. This in turn means that agricultural crops will need more water for their development. Insufficient water is already a limiting factor for normal growth and is compensated for in many cases with irrigation.

An earlier start of the growing season will allow for adaptation to higher average air temperatures, with farmers starting to grow certain crops earlier in the year to avoid the peak hot periods of summer when temperatures and evapotranspiration are high. Any future adjustments to crop management practices, however, must also take into account the possibility of prolonged late spring frosts.

Analysis projects an average increase of air temperatures in the growing season for the south-east region of 0.14°C for the period 2000–2025 and 1.36°C for the period 2000–2050.

An increase in average air temperature of more than 2.04°C can have a serious impact on agricultural production in the south-east region, especially given the intensity of agricultural production in this region, with part of it planted with high intensive cash crops (greenhouses, orchards and vineyards). Such an increase in air temperature will lead to an increase in demand for water and damage to fruits, such as sunburn in grapes, reducing not only yields but also the quality and market value of certain crops.

For these reasons, it is vital to introduce effective measures for increasing the efficiency of water use. Investments in irrigation and applicable adaptation measures in the area of crop management are indispensable and should be coupled with in-depth economic analysis to assess the economic feasibility and cost-effectiveness of these measures.

The findings of the study show that the growing period of all groups of crops with a base temperature of 5.6°C and above will start earlier and the growing stages will be dramatically shifted in time—with the growing period prolonged.

The south-east region will see a greater increase in growing degree days than any other region, making it much more vulnerable to climate change than the rest of the country. There will be increasing differences in plant development phases over the next 40-year period.

The growing season in the south-east region will be shortened in some sub-regions by up to 33 days by 2050, mostly due to the prolongation of the start of the growing season in spring, due to air frosts or cold spells in late spring. A reduction in average annual rainfall can also affect the length of the growing season.

Rainfall

Rainfalls are the only source of water for agricultural crops in many areas not covered with irrigation schemes. Predicting future trends in rainfall was therefore a vital task within the Third National Communication's report on the agricultural sector. However, the number and variety of rainfall regimes that exist in the southeast region make the prediction of future trends in rainfall a complex and challenging task.

The main trend identified in the simulations carried out for the Third National Communication show a decrease in average annual rainfall sums in all sub-regions of the southeast region in the period 2000–2040. Average rainfalls in the southeast region are 94 to 185 mm lower than the averages for rainfall in the whole territory.

The sum of rainfalls for the most rainy months shows a 15% decrease in the period 2000–2040. These calculations also show an increase in intensive rainfalls on certain days.

Intensive rainfalls are highly detrimental for agriculture because soil cannot absorb such large amounts of water, resulting in surface outflow that causes intensive soil erosion and other damage.

Another negative effect of intensive rainfalls is flooding, which can threaten large areas of agriculture.

Spring 2013 saw intensive rainfall in the Strumica valley of the Southeast region, with 64.5–190mm of rain recorded in 3 days, an amount several times higher than average rainfalls for the period 1961–2012.

The assessment found that average rainfalls in the growing season can be expected to drop by up to 15.45 % the simulated period 2000–2050. Any decrease in water during the growing season is harmful for the agricultural sector since there is already a severe shortage of water for current crops in the region—a shortage that has to be made up for through irrigation.

Evapotranspiration

Evapotranspiration—the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants—is another important indicator for assessing the vulnerability of the agricultural sector to climate change. Any changes in air temperature, rainfall, solar radiation, wind-speed, air vapour pressure will have a significant impact on evapotranspiration in terms of total water demand. Using these basic climatological elements to run a simulation, the vulnerability assessment evaluated potential evapotranspiration and identified a clear long-term trend of increasing evapotranspiration in the period 2000–2040, with a total increase of 10.14 per cent. To adapt to future increases in evapotranspiration it will be imperative to make greater and more efficient use of irrigation.

PROJECTED IMPACTS OF CLIMATE CHANGE ON CROP YIELDS

With no adaptation and no irrigation, yields of all crops will decline in the most vulnerable areas of the country.

A number of local studies have been undertaken in recent years to project the impact of climate change on crop yields. Although projections vary significantly, there is general agreement that impacts will be negative after 2050 for a variety of summer and perennial crops across the majority of the country. However, the yield impact on winter crops like wheat is less certain, with both increasing and decreasing yields projected, depending on the assumptions of the underlying studies.

The projections clearly display the spatial variability of yield impacts across the country and the difference between crops for both time periods. For rain-fed wheat, the major growing areas in the continental and Mediterranean agro-ecological zones are projected to experience a moderate increase in yields of up to 10% for both 2025 and 2050. For rain-fed maize, moderate (0-10%) and severe declines in yield (10-25%) are projected for the majority of the country by 2025, followed by severe declines of up to 25% throughout the country by 2050, with some vulnerable areas experiencing even greater declines.

CROP WATER REQUIREMENT AND IRRIGATION WATER

The highest increase in average monthly air temperature will occur during the crop-growing period and this will significantly increase the amount of water needed by crops.

Decreased rainfalls will significantly reduce the supply of water available for crops. Rainfalls are expected to decrease by about 5% by 2025, 12% by year 2050, 18% by 2075 and almost 23% by the end of the century.

While total rainfalls in the growing season will decrease, there will be an increase in winter rainfalls. This can drastically increase irrigation water requirements in the growing season. Agriculture in the Strumica region already depends on irrigation and any further increase in the amount of water required for irrigation will seriously strain water supply in the water-limited catchment area of the River Strumica.

THE EFFECTIVENESS OF ALTERNATIVE ADAPTATION STRATEGIES

To assess the effectiveness of alternative strategies of adaptation to these projected changes in climate—temperature, rainfall, growing season length, etc.— the Third National Communication used the Cropping Systems Simulation Model (CropSyst), a multi-year, multi-crop, daily time step crop growth simulation model.

CropSyst allows for the input of a large amount of inter-related factors to calculate the effect of different options in the management of cropping systems on crop productivity and the environment. In this way, the project was able to run simulations taking into account such complex variables as the soil-plant nutrient budget, crop canopy and root growth, as well as crop characteristics, weather factors, forms of irrigation, pesticide applications and a plethora of other influences on productivity and yield. The model accounts for four limiting factors to crop growth: water, nitrogen, light, and temperature.

Many adaptations strategies have been suggested to overcome the negative impact of climate change on crop yields, especially in vulnerable regions where agriculture is most sensitive to climatic fluctuation. The main agronomic adaptation techniques necessary to maintain current levels of crop production include changes to sowing dates, optimizing irrigation management, reducing plant population density, improving soil moisture by conservative tillage and the choosing of crop cultivars with appropriate thermal requirements.

To identify the most suitable strategy of agro-management for each crop, the Third National Communication Project tested numerous scenarios, comparing them with a baseline scenario.

The baseline scenario assumed no irrigation and sowing dates corresponding to traditional crop management in the study zones. The other scenarios assumed various types of irrigation (sprinklers, drop), varying the volume and frequency of water used for irrigation (60 or 80 mm) and 3 different depths of sowing the seeds.

These scenarios were additionally assessed in terms of their economic viability. The economic feasibility assessment included a cost-benefit analysis of the proposed measures for adaptation, identifying the break-even point of the various scenarios, i.e.

calculating the balance between the costs and benefits and return on investment, and drawing up recommendations as to the most economically viable measures.

The additional costs incurred by the proposed scenarios include: additional water for irrigation; additional fuel for ploughing at an extra depth of 1 cm; reduced yields; and costs of maintaining investment assets such as dams and irrigation systems. Additional income generated by the proposed scenarios include reduced costs and increased yields

The key findings and recommendations for agriculture in the Third National Communication are based on the assumption that farmers will have to invest in water-collection systems and irrigation. This is the most probable case, given that only 20% of the area under cereal cultivation is irrigated and only 30% of farmers own irrigation equipment.

According to official data, around 70% of farmers have access to water. Still, it is highly probable that farmers in the future will face water shortages. In order to satisfy the water need and to ensure timely and quality irrigations, investment in water collection systems will be necessary.

Recommended adaptation scenarios for wheat, maize and sunflower

All adaptation scenarios generate higher crop yields than the baseline scenario of no adaptation. However, the scenarios that generate the highest yields are also those that demand most water. This requires a coordinated intersectoral approach to the planning and allocation of water resources.

In the first analysis period, from 2015 to 2025, the proposed adaptation scenarios can easily counterbalance the negative effects of climate change. In the second period from 2025 to 2050, however, the scenarios only modestly respond to climate change challenges and most scenarios in this period show negative financial results. The Third National Communication therefore recommends combining different adaptation measures, applying certain measures before 2025 and later introducing further adaptations.

Wheat

Wheat occupies some 3,800 hectares in the south-east region, with an average yield of around 8,800 kg per hectare for biomass and 3,400 kg for grain.

Of the five adaptation scenarios tested for wheat, the Third National Communication project indicates that the best adaptation scenario—assuming the need for investment—is delayed planting at a depth of 4 cm instead of 3 cm and twice-yearly irrigation with sprinklers in volumes of 60 mm of water per irrigation. This scenario would have a payback period of 15 years.

The implementation of this scenario at national level would demand an extra 100 million cubic metres of water. However, if this scenario is implemented at national level, it should gain an additional yield of 114,887 tonnes compared with the baseline scenario where no adaptation measures are implemented. This extra wheat production will reduce the country's current dependency on wheat imports and generate an additional EUR 19.20 million paid in the government budget.

Nevertheless, the economical sustainability of this scenario is highly sensitive to even a small reduction in yield. For this and other long-term reasons related to climate change, the Third National Communication recommends that farmers combine this scenario with a higher-yield adaptation scenario that also requires irrigation with sprinklers, but with more frequent sprinkling, i.e., every 20 days in a 60-day period. Like all adaptations that produce the highest yield, more frequent sprinkling will generate greater demand for water. However, this can be economically feasible if subsidies are provided on the selling price or investment in water-collection systems such as dams and reservoirs.

Given the need for investments and subsidies, the Communication recommends that the scenario with less frequent sprinkling should be applied in the period from 2015 to 2025, followed by more frequent sprinkling thereafter.

Maize

Maize is sown on around 3800 ha in the south-east region, with average yields of 3400 kg per hectare. High temperatures, low relative humidity and low rainfall negatively affect maize growth. Without adaptation, maize yields are expected to reduce dramatically: by 23% in 2025 and by 27% in 2050.

Any form and amount of irrigation will increase the yield of maize. Thus all scenarios resulted in yields 35 per cent higher than the losses incurred by not adapting any measures at all (i.e. the baseline scenario of no irrigation).

It will be vital to introduce additional agro-technical measures for growing maize, such as early sowing dates and careful use of mineral fertilizers, especially nitrogen, the growing of new hybrids or substitute crops.

The all-round best adaptation scenario for maize, according to the Third National Communication, is that of irrigation with sprinklers with a volume of 60 mm of water in 4 applications. This scenario has a payback period of 8 years. Even this scenario will result in lower yields of maize in the period up to 2025: about 30% less than the total of current national production. But still this is the scenario with lowest yield reduction. This scenario generates an additional EUR 14.80 million for the government budget.

The implementation of this scenario at national level will demand an extra 100 million cubic metres of water.

Sunflower

Without adaptation, an increase in temperature of 2°C combined with higher evapotranspiration and decreased rainfall will lead to a 30% reduction in sunflower yields by 2025 and a 40% reduction by 2050. Some climate models suggest that even the slowest warming will lead to sunflower yield losses as high as 29 per cent by the end of the century.

Eight scenarios were developed to compare the effect of different adaptation measures for sunflower production. Several adaptation scenarios were found to have the potential to become economically feasible. However, sunflower production will need to be subsidized in order to ensure economic feasibility.

The Third National Communication identified the most effective adaptation measures for sunflower to be planting at a depth of 5 cm instead of 4 cm and irrigation with sprinklers three times with 50 mm of water. For this scenario to be economically feasible, however, the selling price of sunflower will need to be raised from 0.49 to 0.63 euros, or an additional subsidy of 0.14 euros on the selling price.

If implemented at national level, this scenario will gain an extra sunflower yield of 1,673 tonnes, representing 30% of the current national production of sunflower.

This scenario can be sustainable only if famers invest a maximum of EUR 427 in water collecting systems. The difference between the maximum investment that farmers can afford and the full construction value of investment in water collecting systems must to be subsidized.

To further reduce the impact of climate change on sunflower productivity, the Third National Communication recommends the development or breeding of new sunflower hybrids more tolerant to higher temperature and adverse climatic conditions, changes in sowing methods and dates, irrigation and fertilizer use, insect pest and disease management.

Further recommendations

The simulations indicate that substantial yields of wheat, maize and sunflower can be achieved up to 2025 in the south-east region despite climate change through the adjustment of sowing dates and the use of irrigation. However, the period 2025–2050 will be far more critical. Additional modelling studies are needed to explore the impact on yields of increased CO_2 and water consumption and to identify the most effective agro-management techniques that could reduce the negative impacts of climate change.

A national support program should be developed for wheat and sunflower to ensure economic feasibility. Support can be provided in the form of subsides for prices or subsidies for investment in water-collection systems and irrigation. Some of the subsidies needed for water collecting systems can be returned by the extra taxes paid on the additional yields achieved with the implementation of the scenarios.

Close intersectoral and institutional cooperation is needed to ensure the successful implementation of the adaptation scenarios.

It will be necessary to develop an efficient system of monitoring and evaluation to gather regular evidence and conduct comparative analysis of the results obtained from the implementation of the scenarios and the results obtained from models. Such a monitoring and evaluation system would provide a better overview of the results and enable timely response and fine-tuning of the adaptation measures.

The sucess of this approach used in the Third National Communication on Climate Change i.e. scenario modelling and evaluation, was a baseline for replicating it also in the Povardarie Planning Region to assess climate change impact on viticulture. Key findings and recommendations are:

- The Growing Season Length in the Povardarie region of Macedonia will be shortened by a maximum of 30 days.
- Without irrigation there will be a reduction in yields of table grapes from 26 tons in 2000 to 25 tons in 2025, and to 24 tons in 2050. Yields of wine grape will also be reduced, from almost 12 tons in 2000 to 11 tons in 2025 and to 10 tons in 2050.
- With drip irrigation, the increase in grape yields will be in the range of 22% and 26% for 2025 and 2050 respectively.
- Timely and appropriate irrigation will mitigate the effects of high temperatures and will contribute to increased production.
- UV nets completely change the microclimate in vineyards by decreasing the temperature of the air and the grapes, preventing the occurrence of diseases caused by precipitation, and removing the risk from hail events. The use of UV nets as an adaptation measure to climate change has a positive effect on the yield of table and wine grapes.
- Relocating vineyards to an altitude 250m higher significantly increases yields and causes a 15-day delay in the maturation of grapes.

It is highly recommended to use this approach in other planning regions in the country for assesssing climate change impact on most prevalent crops.

Climate change & food security

Climate change will affect all aspects of food security, including the stability of food supplies, prices and access to food. At the same time, urbanization and globalization are causing rapid changes to food systems.

Low-income agricultural production systems will be more vulnerable to reductions in food production because they have a limited capacity to adapt or respond to changes.

The indirect effects of climate change on pests, plant diseases and food safety should also be taken into account. Increased temperatures and heavy rains can develop an environment for rapid microbial infections that can cause food poisoning and multiplication of pathogenic microorganisms in food.

This situation will lead to greater use of chemicals to protect crops against diseases, which in turn will affect the profitability of production. It will further lead farmers to switch to crop varieties more resistant to disease and other impacts of climate change.

The severity of the impacts of climate change will crucially depend on the future policy environment. This requires an integrated and focused framework that allows policy makers, researchers and implementers to develop appropriate tools and programmes to facilitate farmers and local governments to adapt to climate change.