CHINA — BULGARIA

Rural Climate Risk Assessment Report

Bulgaria

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RURAL CLIMATE RISK ASSESSMENT REPORT - BULGARIA

Content

Executive summary

Rural communities are highly dependent upon natural resources that are affected by climate change. These communities also face particular obstacles in responding to climate change that increase their vulnerability to its impacts. Urban areas that depend on goods and services from rural areas will also be affected by climate change driven impacts across the countryside. In Bulgaria, rural areas provide natural resources for the country, including food, energy, water, forests, recreation, national character, and quality of life. Rural economic foundations and community cohesion are intricately linked to these natural systems, which are inherently vulnerable to climate change. Agriculture is also one of Bulgaria's main industries.

In this report, we draw on climate model forecasts to showcase how the climate has changed and could continue to change, how a changing climate creates new risks and uncertainties, and what steps can be taken to best manage them in Bulgarian rural area. Climate impact research makes extensive use of scenarios. Three “Shared Socioeconomic Pathways” (SSPs) act as standardized inputs to climate models. They outline different atmospheric greenhouse gas concentration trajectories. During their inception, SSPs were designed to collectively sample the range of then-probable future emission pathways, ranging from lower (SSP126) to higher (SSP585) CO_2 concentrations. Using data from 13 global climate models in the Coupled Model Intercomparison Project Phase 6 (CMIP6) and historical climate data, temperature and participation simulation was made for Bulgaria. This process aims to analyze the overall changes in temperature and precipitation in Bulgaria over a 75-year period, divided into three phases: 2025-2050 (early period), 2050-2075 (mid-term), and 2075-2100 (long-term).Based on the climate simulation, we examine the impacts of climate change to key sectors in rural area: agriculture, forestry, water and energy. Policy framework for climate adaptation in rural area was made, and climate adaption recommendations was proposed.

This report is intended to provide overviews of trends and projected changes in key climate parameters, sector-specific implications, relevant policies and programs,

adaptation priorities and opportunities for further actions in Bulgarian rural area.

1. Introduction

After more than 10,000 years of relative stability—the full span of human civilization—the Earth's climate is changing. As average temperatures rise, acute hazards such as heat waves and floods grow in frequency and severity, and chronic hazards, such as drought and rising sea levels, intensify. Climate change is already having substantial physical impacts at a local level in regions across the world; the affected regions will continue to grow in number and size. Since the 1880s, the average global temperature has risen by about 1.1 degrees Celsius with significant regional variations （IPCC, 2022）. This brings higher probabilities of extreme temperatures and an intensification of hazards. A changing climate in the next decade, and probably beyond, means the number and size of regions affected by substantial physical impacts will continue to grow.

Projected risks and impacts of climate change on natural and human systems at different global warming levels (GWLs) relative to 1850-1900 levels. In the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), Work Group II (WGII) provides assessment of the impacts on human and natural systems using these projections and additional lines of evidence (IPCC, 2022). (a) Risks of species losses as indicated by the percentage of assessed species exposed to potentially dangerous temperature conditions, as defined by conditions beyond the estimated historical (1850-2005) maximum mean annual temperature experienced by each species, at GWLs of 1.5oC, 2oC,3oC and 4oC. Underpinning projections of temperature are from 21 Earth system models and do not consider extreme events impacting ecosystems such as the Arctic. (b) Risks to human health as indicated by the days per year of population exposure to hyperthermic conditions that pose a risk of mortality from surface air temperature and humidity conditions for historical period (1991-2005) and at GWLs of 1.7°C–2.3°C (mean = 1.9°C; 13 climate models), 2.4°C–3.1°C (2.7°C; 16 climate models) and 4.2°C–5.4°C (4.7°C; 15 climate models). Interquartile ranges of GWLs by 2081–2100 under RCP2.6, RCP4.5 and RCP8.5. The presented index is consistent with common features found in many indices included within WGI and WGII assessments (c) Impacts on food production: (c1) Changes in maize yield by 2080–2099 relative to 1986–2005 at projected GWLs of 1.6°C–2.4oC (2.0°C), 3.3°C–4.8oC (4.1°C) and 3.9°C–6.0oC (4.9°C). Median yield changes from an ensemble of 12 crop models, each driven by bias-adjusted outputs from 5 Earth system models, from the Agricultural Model Intercomparison and Improvement Project (AgMIP) and the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP). Maps depict 2080–2099 compared to 1986–2005 for current growing regions (>10 ha), with the corresponding range of future global warming levels shown under SSP1-2.6, SSP3-7.0 and SSP5-8.5, respectively. Hatching indicates areas where {`<`}70% of the climate-crop model combinations agree on the sign of impact. (c2) Change in maximum fisheries catch potential by 2081–2099 relative to 1986–2005 at projected GWLs of 0.9°C–2.0°C (1.5°C) and 3.4°C–5.2°C (4.3°C). GWLs by 2081–2100 under RCP2.6 and RCP8.5. Hatching indicates where the two climate-fisheries models disagree in the direction of change. Large relative changes in low yielding regions may correspond to small absolute changes. Biodiversity and fisheries in Antarctica were not analyzed due to data limitations. Food security is also affected by crop and fishery failures not presented here.

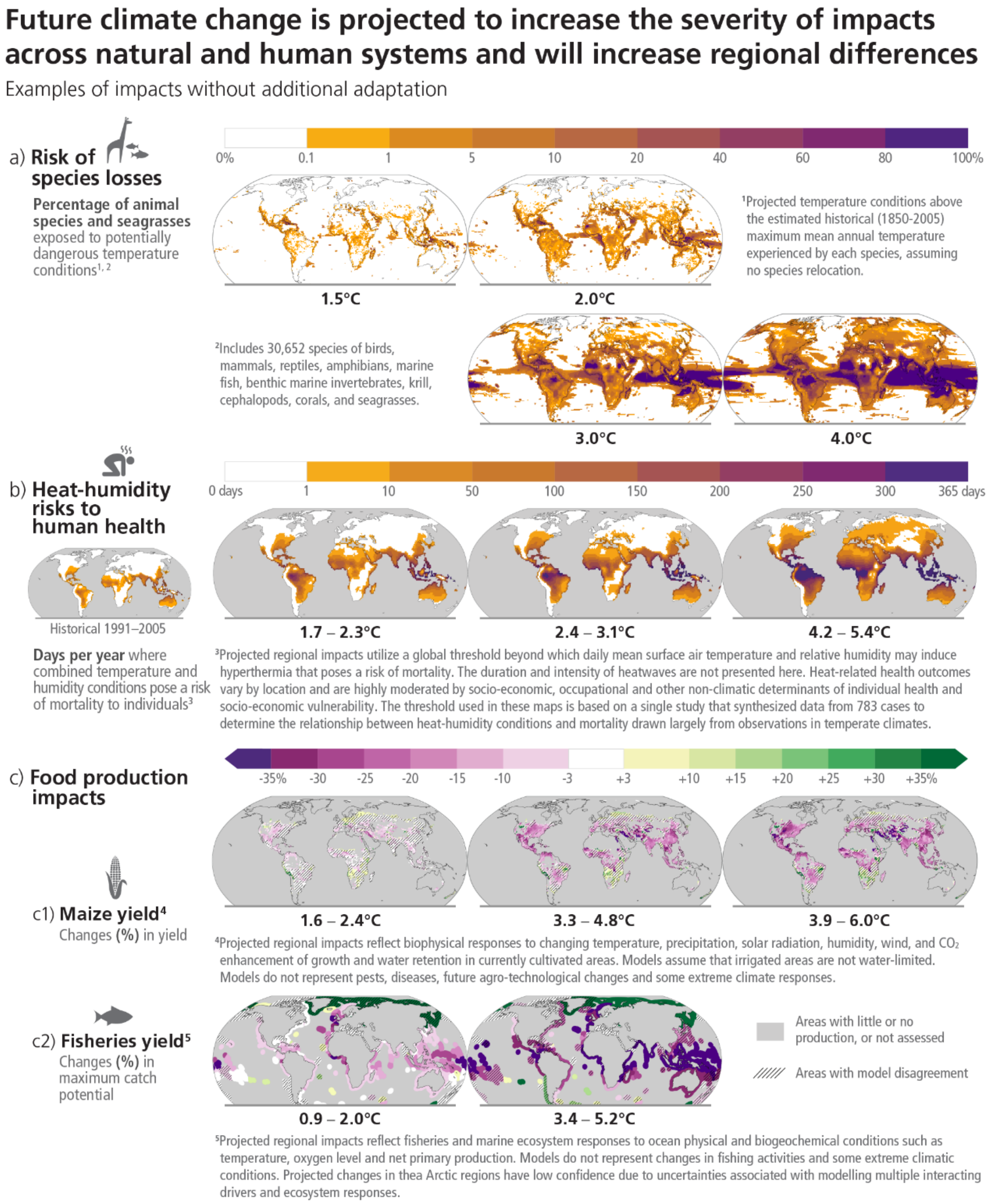


Figure 1.1 Example of climate change impacts without additional adaption (Source: IPCC, 2022)

1.1 Understanding climate risk

A changing climate is introducing new risks that are significant today and will grow. These risks can be grouped into three types: physical risk (risks arising from the physical effects of climate change); transition risk (risks arising from transition to a low-carbon economy); and liability risk (risks arising from those affected by climate change seeking compensation for losses). This report mainly focused on the physical risk from a changing climate, and the potential effects on rural area, including people, communities, and economic activity, and the implications for agriculture industries, governments, and individuals. We do not focus on transition risks or liability risks associated with climate change in this report.

The global temperature has risen by 1.1 ° C, and all regions of the world are facing unprecedented climate system changes, from sea level rise, frequent extreme weather events, to rapid melting of sea ice. Further increases in temperature will further exacerbate these changes. For example, for every 0.5 ° C increase in global temperature, extreme high temperatures, heavy rainfall, and regional droughts become more frequent and severe. In the absence of human activity, heatwaves only occur once every 10 years on average. When the average temperature increases by 1.5 ° C, 2 ° C, and 4 ° C, the frequency of high-temperature heat waves may increase by 4.1 times, 5.6 times, and 9.4 times, respectively, and their intensity may also increase by 1.9 ° C, 2.6 ° C, and 5.1 ° C, respectively. The rise in global temperatures also increases the risk of the climate system reaching critical points. Temperature crossing the critical point may trigger internal enhancement effects such as permafrost melting or large-scale forest withering, exacerbating the trend of global warming, which will further lead to sudden and irreversible substantive changes in the climate system. For example, if the average temperature increases by 2 ° C to 3 ° C, almost all ice sheets in western Antarctica and Greenland may melt irreversibly for thousands of years, causing sea levels to rise by several meters.

The impact of climate on humans and ecosystems far exceeds expectations, and risks will rapidly escalate as climate warming intensifies. Currently, about half of the global population faces severe water shortages for at least one month each year, and rising temperatures have exacerbated the spread of vector borne diseases such as malaria, West Nile virus, and Lyme disease. Climate change has also hindered the growth of agricultural productivity in mid to low latitude regions. Since 1961, the growth rate of crop productivity in Africa has decreased by one-third. Since 2008, extreme floods and storms have forced over 20 million people to leave their homes every year.

Every few tenths of a degree Celsius increase in temperature exacerbates these crises. Even if the global temperature rise is controlled within 1.5 ° C, it cannot guarantee that everyone's life safety will not be affected. For example, under the current trend of temperature rise, 950 million people living in arid regions around the world will face a series of problems such as water pressure, heatstroke, and desertification, while the proportion of people affected by floods worldwide will increase by 24%.

Similarly, even if the temperature rise temporarily exceeds 1.5 ° C, it can lead to serious and irreversible effects, including local species extinction, complete inundation of salt marshes, and even human death due to increasing extreme high temperatures. Therefore, controlling the amplitude and duration of temperature rise exceeding 1.5 ° C, and controlling it as much as possible at a level of 1.5 ° C or lower, is crucial to ensure a safe and livable future.

1.2 Changing climate and its impact to rural area

Bulgaria covers an area of 110 900 km² of which 81 % is rural. Of the total area, 46.1 % is agricultural land while forests cover 37.4 %. The total population is 7.28 million – of which 39 % live in rural areas. Rural areas provide natural resources, food, energy, water, forests, and recreation. The agricultural sector contributes to 6 % of the country's Gross Value Added (GVA) and 18.3 % of the work places, while the food industry has a share of 3.8 % in the GVA and 3.4 % in the employment. The structure of agricultural holdings is polarized - although an average holding in Bulgaria utilizes 12 ha of land, 91 % of the country's 370 500 agricultural holdings have less than 5 ha. The average economic size of an agricultural holding is € 6 847. 23% of farms are in the range of € 2 000 – € 7 999 and they contribute to 24 % of the agricultural employment. Certain traditional agricultural sectors (such as fruit and vegetables, and livestock) are underperforming and experiencing structural difficulties.

Rural economic foundations and community cohesion are intricately linked to these natural systems, which are inherently vulnerable to climate change. Urban areas that depend on goods and services from rural areas will also be affected by climate change driven impacts across the countryside.

Warming trends, climate volatility, extreme weather events, and environmental change affect the economies and cultures of rural areas. Rural communities face considerable risk to their infrastructure, livelihoods, and quality of life from observed and projected climate shifts. These changes will progressively increase volatility in food commodity markets, shift the ranges of plant and animal species, and, depending on the region, increase water scarcity, exacerbate flooding and coastal erosion, and increase the intensity and frequency of wildfires across the rural landscape.

Climate changes will severely challenge many rural communities, shifting locations where particular economic activities are capable of thriving. Changes in the timing of seasons, temperatures, and precipitation will alter where commodities, value-added crops, and recreational activities are best suited. Because many rural communities are less diverse than urban areas in their economic activities, changes in the viability of one traditional economic sector will place disproportionate stresses on community stability.

Climate change impacts will not be uniform or consistent across rural areas, and some communities may benefit from climate change. In the short term, the Bulgarian agricultural system is expected to be fairly resilient to climate change due to the system's flexibility to engage in adaptive behaviors such as expansion of irrigated acreage, regional shifts in acreage for specific crops, crop rotations, changes to management decisions (such as choice and timing of inputs and cultivation practices), and altered trade patterns compensating for yield changes. Recreation, tourism, and leisure activities in some regions will benefit from shifts in temperature and precipitation.

Negative impacts from projected climate changes, however, will ripple throughout rural area in Bulgaria. Agricultural systems in some areas may need to undergo more transformative changes to keep pace with future climate change. In lakes and riparian areas, warming is projected to increase the growth of algae and invasive species, particularly in areas already facing water quality impairments. Climate change can make conditions worse for growing crops in different regions. For example, changes in temperature, rainfall, and frost-free days are leading to longer growing seasons. A longer growing season can have both positive and negative impacts for raising food. Some farmers may be able to plant longer-maturing crops or more crop cycles altogether, while others may need to provide more irrigation over a longer, hotter growing season. Air pollution may also damage crops, plants, and forests. For example, when plants absorb large amounts of ground-level ozone, they experience reduced photosynthesis, slower growth, and higher sensitivity to diseases.

Climate change can also increase the threat of wildfires. Wildfires pose major risks to farmlands, grasslands, and rangelands. Temperature and precipitation changes will also very likely expand the occurrence and range of insects, weeds, and diseases. This could lead to a greater need for weed and pest control.

2. Bulgaria climate-present and future

2.1 Climate overview

Bulgaria has two climate zones: the northern region has a continental climate, and the southern region has a Mediterranean climate. The Mediterranean climate of the country is hot and dry in summer and cool in winter. The distinction between the mountains in the northern and southern regions has a significant impact on the temperature of the country (Alexandrov et al., 2004). Compared to coastal areas, the temperature and precipitation changes in the northern part of the mainland are often greater (National Institute of Meteorology and Hydrology, 2018). Approximately 50% (5.2 million hectares) of the territory is agricultural land. It is estimated that 29.5% of the area is used for irrigation. Forests cover 34% of the total area of the country (FAO, 2017).

The mean monthly temperature in Bulgaria ranges from −1°C to 22 °C. Coldest temperatures are experienced in the northern winter months of December and January and warmest temperatures during northern hemisphere summer months of July and August (WBG, 2020). Over the past century, the region has experienced gradual warming, while the intensity and length of heat waves in the Mediterranean region have increased (Lelieveld et al., 2012). The average monthly precipitation ranges from 40 to 71 millimeters and varies seasonally; May and June have the highest precipitation, while the two periods (February and March, as well as August and September) have the lowest precipitation. Over the past century, precipitation has varied greatly, and recent short-term increases in precipitation have led to floods.

2.2 Current trends in Bulgaria climate

2.2.1 Temperature

The temperature in Bulgaria ranges from 15 ° C to 25 ° C, steadily increasing from March to June. Summer usually starts in early June, with temperatures typically reaching over 30 ° C. July and August are the hottest months, with the highest temperature in summer reaching 35 ° C to 38 ° C or above. Summer usually ends in mid-September, when the temperature drops and the days become shorter. September and October are usually warm, with temperatures ranging from 10 ° C to 25 ° C. However, Bulgaria has experienced a warming trend over the past century, with the difference between the highest and lowest temperatures decreasing (Figure 4). The annual average temperature continues to exceed the historical record of average temperature and continues to reach a new historical high. From 1988 to 2016, the average annual temperature in lower areas of the country (below 800 meters above sea level) increased by 0.8 ° C. Since the 1970s, a warming trend has been observed. In 2014, it reached the highest temperature since 1901, with an annual average temperature of 12 ° C, 1.45 ° C higher than the average temperature. The annual average temperature observed in 2015 was 1.12 ° C higher than the average temperature. Overall, the winter in Bulgaria was relatively mild in the second half of the 20th century, with more and more periods of high temperatures and drought (Republic of Bulgaria, 2018).

2.2.2 Precipitation

Dobrudzha in the northeast, the Black Sea coastal area, and parts of the Thracian Lowland usually receive less than 500 mm precipitation per year. The Thrace lowlands often suffer from summer drought. High altitude areas have the highest precipitation in the country, averaging over 1000 to 1100 millimeters per year. The precipitation varies greatly across the country. For example, the annual average precipitation in Bulgaria in 2013 was 49.7 millimeters, 1.7 millimeters lower than the average level, while the rainfall in 2014 was 80.9 millimeters, 29.4 millimeters higher than the normal level. The average annual precipitation in 2015 was 60.4 millimeters, 8.9 millimeters higher than the average level. We also observed an increase in the frequency of extreme rainfall and precipitation events, especially on days with high precipitation (volume exceeding 100 millimeters). The snow moon has decreased, the snow cover has significantly decreased, and the upper limit and sound of the deciduous forest have also changed. (Republic of Bulgaria, 2018)

2.3 Future climate simulation in Bulgaria

2.3.1 Data sources

The study of relevant papers under the background of climate change in CMIP6 focuses on three criteria for model selection: accuracy, applicability, and data availability of the models as applied in Bulgaria. Ultimately, 13 CMIP6 global models were selected, as detailed in the following table.

Table2-1 Global model information sheet

Serial number	Model name	Organization	Spatial resolution
1	ACCESS-ESM1-5	CSIRO	1.875°×1.25°
2	BCC-CSM2-	Beijing Climate Center	1.120°×1.120°
3	CanESM5	the Canadian Centre for Climate Modelling and Analysis	2.810°×2.770°
4	CMCC-ESM2	CMCC	1.120°×1.120°
5	CNRM-CM6-1	CNRM	1.406°×1.389°
6	CNRM-ESM2-1	CNRM	1.406°×1.389°
7	INM-CM4-8	Russian Institude for Numerical Mathematics Climate Model	2.000°×1.500°
8	INM-CM5-0	Russian Institude for Numerical Mathematics Climate Model	2.000°×1.500°
9	IPSL-CM6A-LR	IPSL	2.5°×1.27°
10	MIROC6	MRI(Meteorological Research Institute)	1.400°×1.400°
11	MRI-ESM2-0	MRI	1.4°×1.4°
12	NorESM2-LM	NCC	
13	NorESM2-MM	NCC	

2.3.2 Downscaling of Statistics

Due to the high spatial resolution of global climate model data, it is necessary to perform down-scaling processing before these data can be applied to community climate prediction. Statistical downscaling mainly includes methods like bias correction of probability, quantile correction, and the Delta method. Compared to other statistical down-scaling methods, the Delta downscaling can effectively reduce the systematic bias between global climate models and regional climate, while retaining the fluctuation characteristics of the global model based on land surface processes and global circulation physical parameterization processes. Therefore, the Delta method is chosen for downscaling. This method corrects the prediction data of the global model by comparing the differences between the historical data of the global model and observational data. The calculation methods are shown in formulas (1), (2), (3), and (4).

Climate:

$$delta_{ymoni\_tmax} = gcm_{ymoni\_tmax} - obs_{ymoni\_tmax} \quad (1)$$

$$gcm(downscaled)_{dailyi\_tmax} = gcm_{dailyi\_tmax} - delta_{ymoni\_tmax} \quad (2)$$

precipitation:

$$delta_{ymoni\_p} = obs_{ymoni\_p} / gcm_{ymoni\_p} \quad (3)$$

$$gcm(downscaled)_{dailyi\_p} = gcm_{dailyi\_p} \times delta_{ymoni\_p}. \quad (4)$$

Where, gcm_{ymoni_tmax} is the long-term monthly average of daily maximum temperature from historical global model data. obs_{ymoni_tmax} is the long-term monthly average of daily maximum temperature from meteorological station observational data, and gcm_{dailyi_tmax} is the daily maximum temperature from global model temperature prediction data. gcm_{ymoni_p} is the long-term monthly average of precipitation from historical global model data. obs_{ymoni_p} is the long-term monthly average of precipitation from meteorological station observational data, and gcm_{dailyi_p} is the daily precipitation after downscaling of global model data.

2.3.3 Analysis of Spatio-temporal Variation Predictions for Future Climate and Precipitation in Bulgaria Using a Multi-Model Ensemble Approach

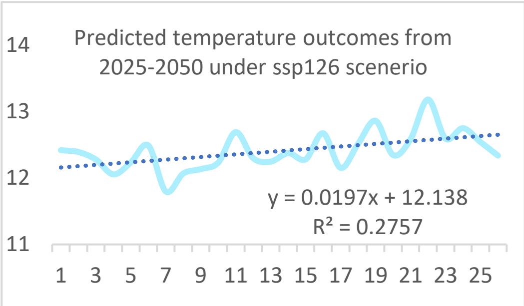
(1) Temporal Trends of Temperature and Precipitation Variability

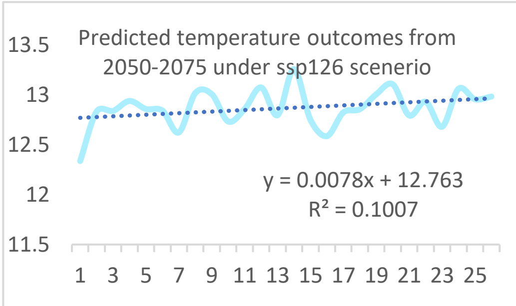
The selected 13 models were subjected to downscaling under three scenarios: SSP126, SSP245, and SSP585, and multi-model ensemble averages were performed. This process aims to analyze the overall changes in temperature and precipitation in Bulgaria over a 75-year period, divided into three phases: 2025-2050 (early period), 2050-2075 (mid-term), and 2075-2100 (long-term).

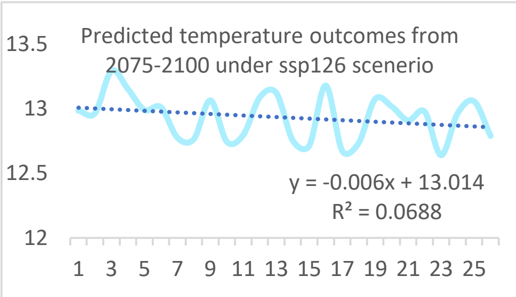
Temperature Forecast Results

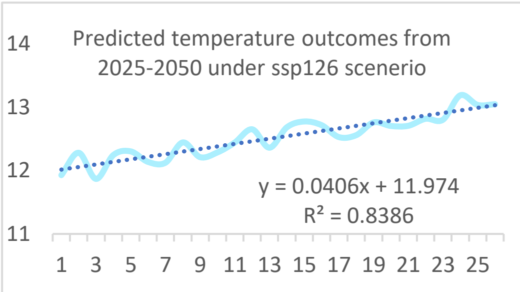
Analysis from the following chart indicates that Bulgaria is projected to experience a fluctuating upward trend in temperature from 2025 to 2100. Specifically, the fastest rate of temperature increase is observed during 2025-2050, with an average acceleration of 0.0399. In contrast, the slowest rate of temperature increase is anticipated between

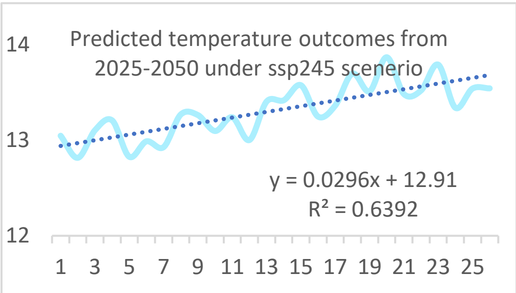
2075 and 2100, with an average acceleration of 0.0299. The temperature rise rate in the early phase ranges from 0.0197 to 0.0596, while the mid-term increase ranges from 0.0078 to 0.0688, and the long-term increase ranges from -0.006 to 0.0763. It is evident that Bulgaria will experience more intense fluctuations in temperature over the long term, with a relatively stable increase in temperature in the early phase.

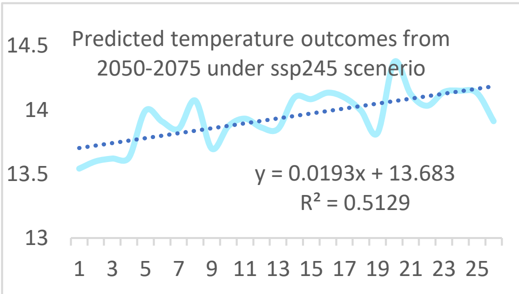


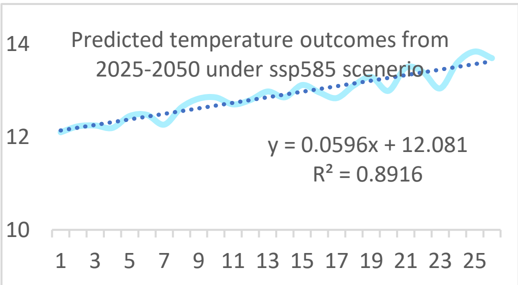


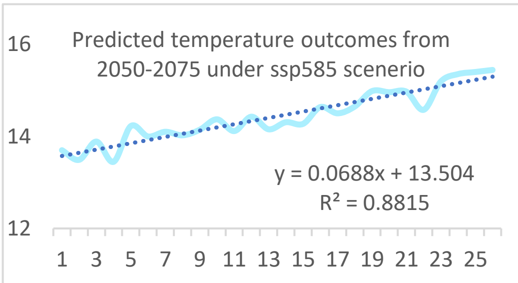












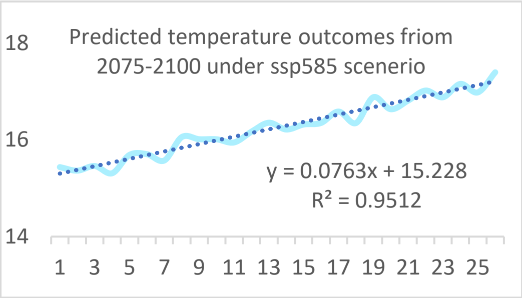


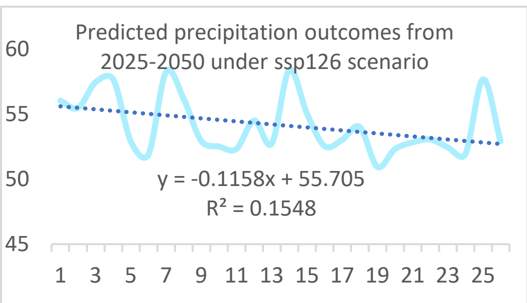
Figure 2-1 Temperature Changes in Bulgaria from 2025 to 2100 Under Different Scenarios

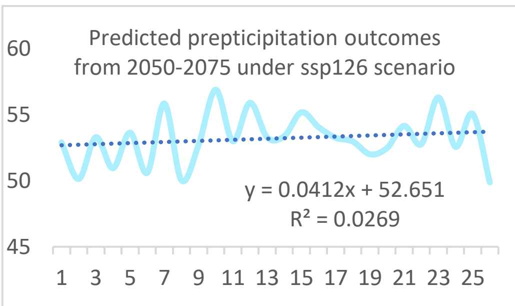
Table 2-2 Summary of temperature predictions

Period	Near term	Middle term	Long term
Range 0f annual temperature growth rates	[0.0197,0.0596]	[0.0078,0.0688]	[-0.006,0.0763]
Average annual temperature growth rates	0.0399	0.0354	0.0299

Precipitation Forecast Results

Analysis of the data presented in the following chart reveals that Bulgaria is expected to experience a fluctuating downward trend in precipitation from 2025 to 2100. Specifically, the period from 2025 to 2050 will see the fastest rate of decline with minimal fluctuation, having an average rate of decrease at -0.1007. Conversely, the period from 2075 to 2100 is characterized by the slowest decline in precipitation, with an average rate of -0.0047 and the highest fluctuation. The rate of precipitation decreases ranges from [-0.1158, -0.0826] in the early phase, [-0.1594, 0.0412] in the mid-term, and [-0.0596, 0.1021] in the long term. This downward trend in precipitation could potentially impact agricultural development in Bulgaria.





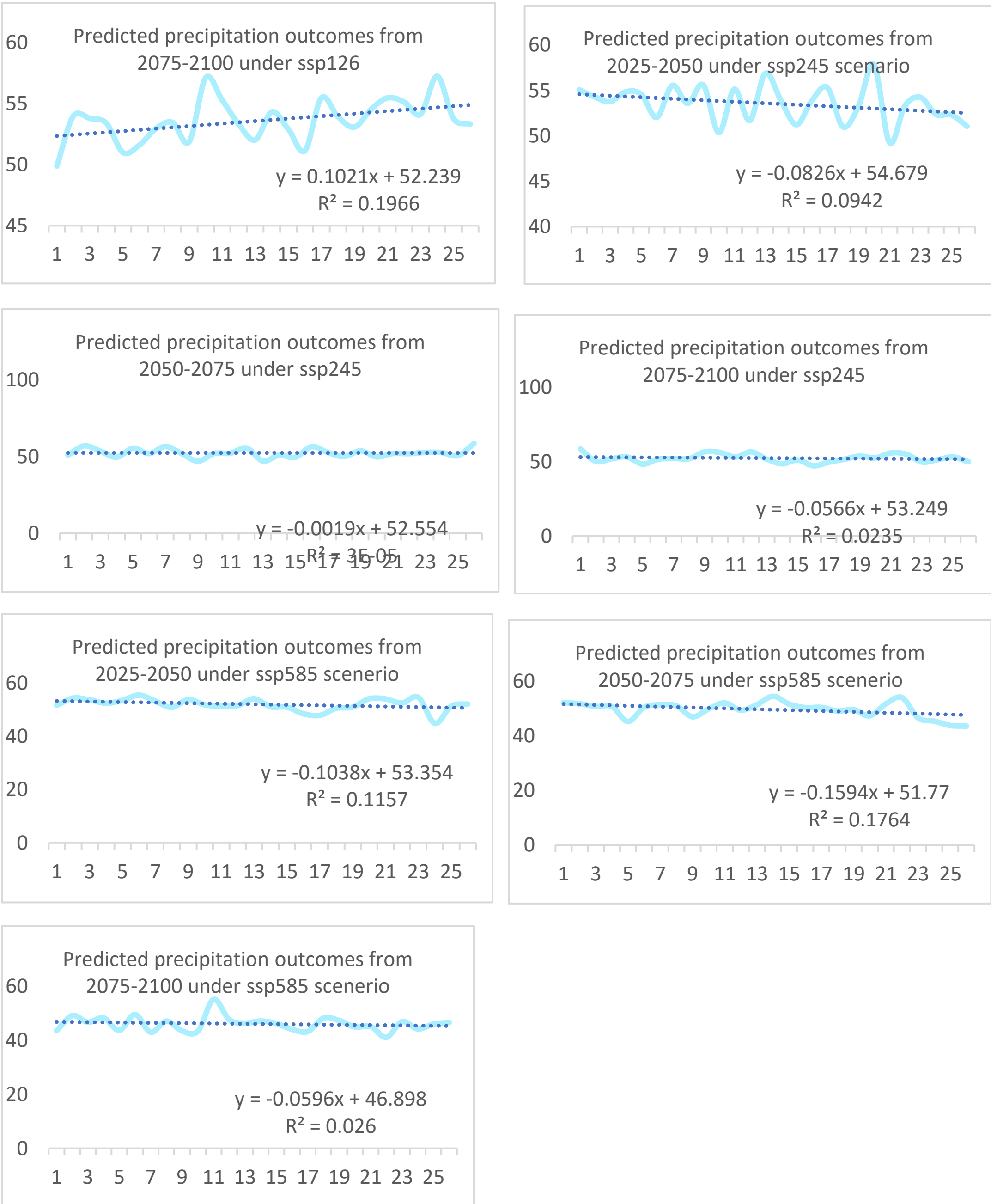


Figure 2-2 Precipitation Changes in Bulgaria from 2025 to 2100 Under Different Scenarios

Table 2-3 Summary of precipitation predictions

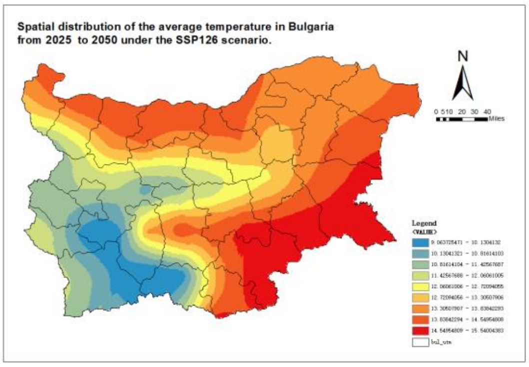
Period	Near term	Middle term	Long term
Range 0f annual precipitation growth rates	[-0.1158,-0.0826]	[-0.1594,0.0412]	[-0.0596,0.1021]
Average annual precipitation growth rates	-0.1007	-0.04	-0.0047

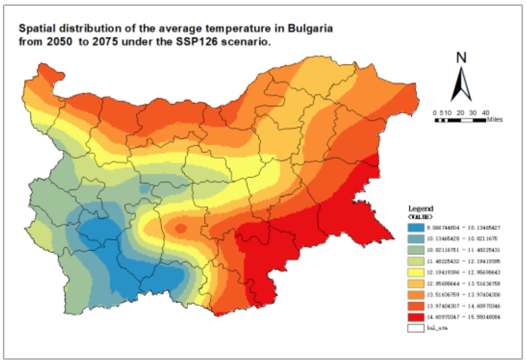
(2) Spatial Variation Trends of Temperature and Precipitation

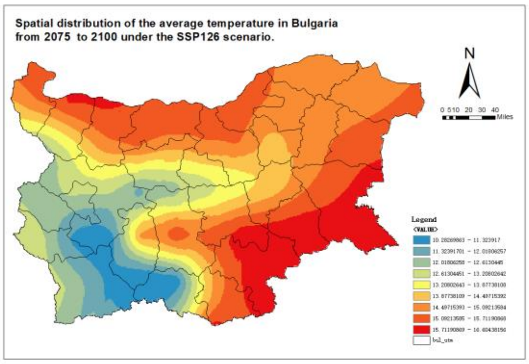
The grid temperature and precipitation data obtained from the above models are averaged across multiple models, and the annual average temperature and precipitation distributions for the years 2025-2050, 2050-2075, and 2075-2100 are calculated separately under the SSP126, SSP245, and SSP585 scenarios. This analysis examines the spatial changes in temperature in Bulgaria in the short-term, mid-term, and long-term periods.

Spatial Distribution Results of Temperature Prediction

Analysis of the below figure reveals that the temperature distribution in Bulgaria presents a "layered structure with gradually increasing temperatures from the southwest direction outward," with the highest temperatures in the southeast region. Examining the changes in spatial distribution of temperature over three time periods, it can be observed that in the future, the areas of red (hot) and blue (cold) temperatures are gradually diminishing, while the regions of intermediate colors are increasing. This indicates a trend of decreasing high and low temperatures, but an overall rise in average temperature. Additionally, there is an increasing trend of temperature increments moving from the periphery towards the center.






Spatial distribution of the average temperature in Bulgaria
from 2075 to 2100 under the SSP126 scenario.
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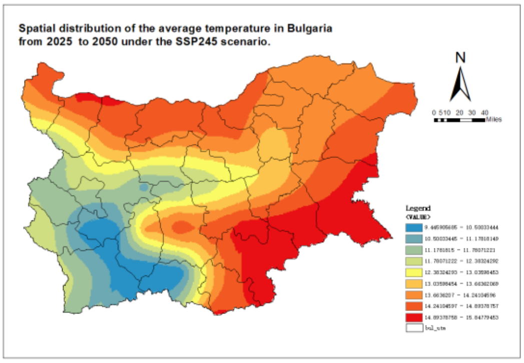
Miles
Legend


Spatial distribution of the average temperature in Bulgaria
from 2025 to 2050 under the SSP245 scenario.
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0 5 10 20 30 40
Miles
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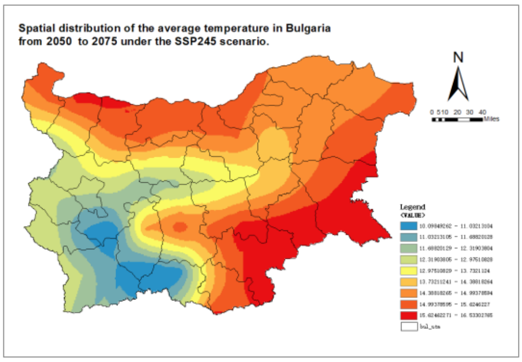
Spatial distribution of the average temperature in Bulgaria
from 2050 to 2075 under the SSP245 scenario.
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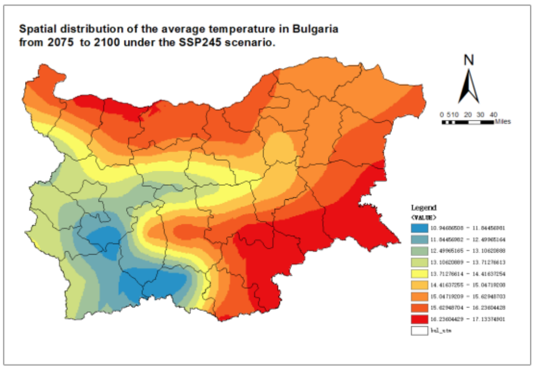
Spatial distribution of the average temperature in Bulgaria
from 2075 to 2100 under the SSP245 scenario.
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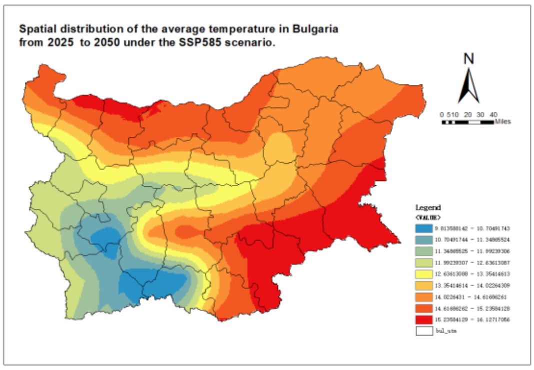
Spatial distribution of the average temperature in Bulgaria
from 2025 to 2050 under the SSP585 scenario.
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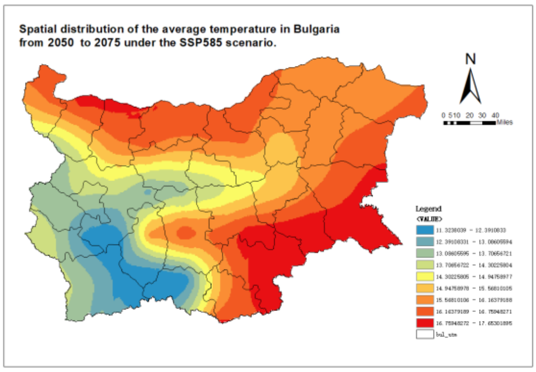
Spatial distribution of the average temperature in Bulgaria
from 2050 to 2075 under the SSP585 scenario.
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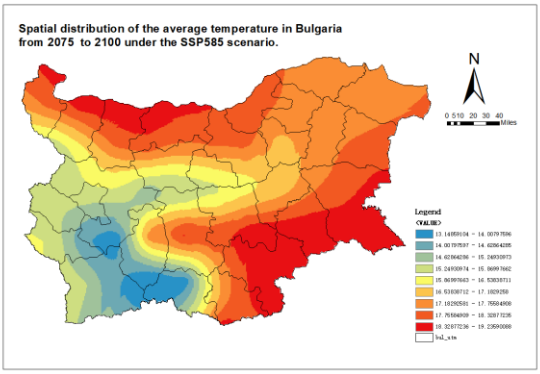
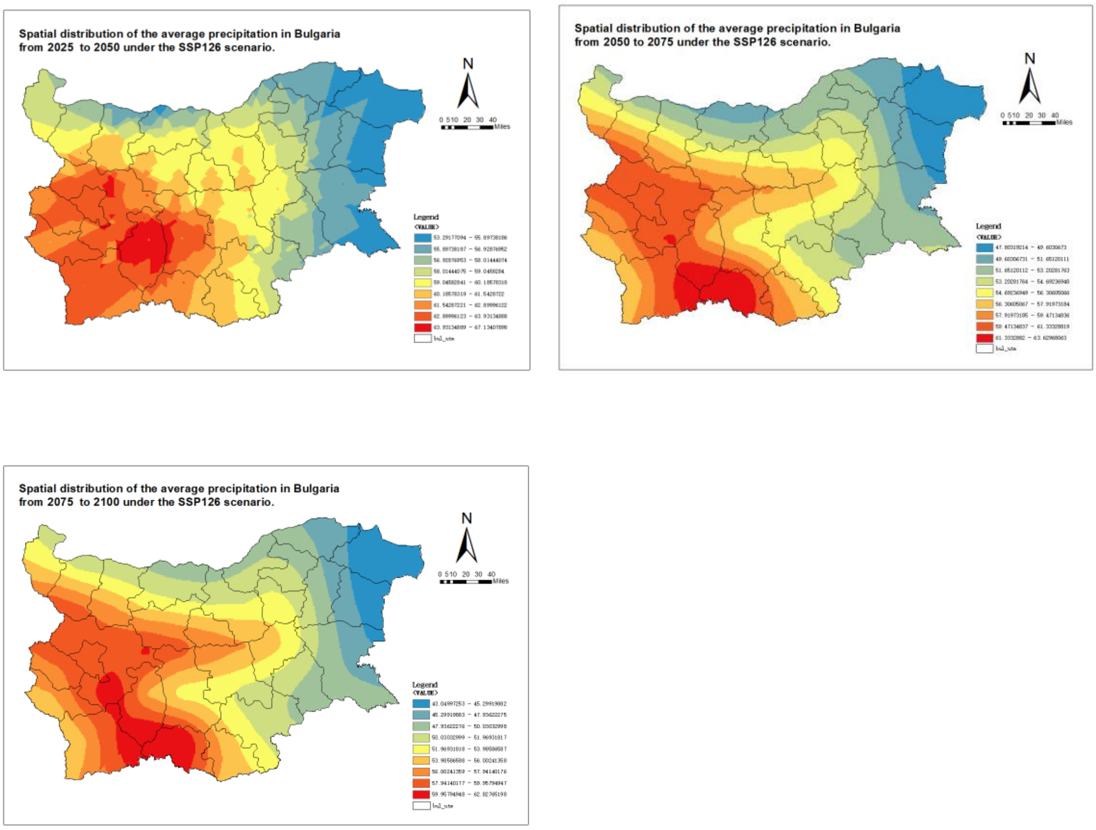


Figure 2-3 The Spatial Distribution of Temperature in Near, Mid, and Long-Term Phases under Three Scenarios

Spatial Distribution Results of Precipitation Prediction

The analysis of the figure below indicates a spatial distribution trend of precipitation decreasing gradually from southwest to northeast. Over time, from the initial to the later period, there is a trend of decreasing precipitation, with the red areas (indicating reduction) expanding and the blue areas (indicating increase) growing. This demonstrates a trend of precipitation decreasing gradually inward from both the southwest and northeast.



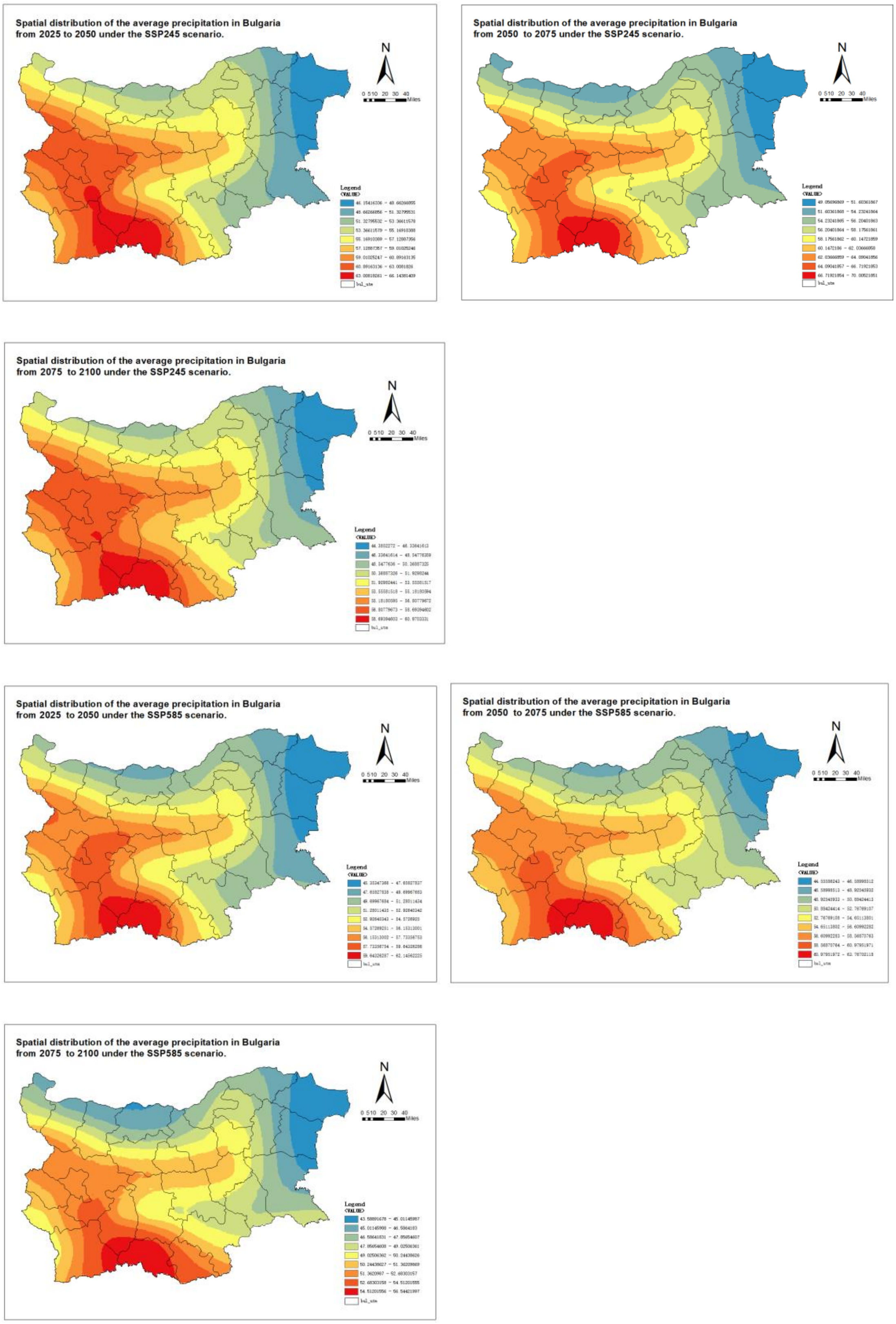


Figure 2-4 The Spatial Distribution of Precipitation in Near Mid, and Long-Term Phases under Three Scenarios

2.3.4 Summary of Future Climate Conditions in Bulgaria

In Bulgaria, the temperature from 2025 to 2100 is projected to show a fluctuating upward trend, while precipitation is expected to demonstrate a fluctuating downward trend. During 2025-2050, the temperature is anticipated to increase at the fastest rate, with an average increase of 0.0399, and precipitation is expected to decrease at the fastest rate, with an average decrease of -0.1007, potentially leading to extreme high temperatures and drought hazards in the near term. The temperature in Bulgaria is expected to exhibit a trend of expansion outward from the southwest, while precipitation is projected to gradually decrease from the southwest outward. Between 2025 and 2100, both precipitation and temperature are expected to gradually expand towards the center, with an overall decrease in precipitation and an increase in temperature.

3. Climate hazards and disasters in Bulgarian rural area

3.1 Overview

In the past decade, scientists have reached a clear consensus that the world is experiencing a rapid global climate change, most of which can be attributed to human activities. The extent of the impact of climate change is difficult to determine, for example, changes in crop yields due to future temperature increases. Because there are many uncertainties regarding how the climate will change and the socio-economic factors that will affect the magnitude of this change.

Currently, Bulgaria is classified as a high-risk area for river floods, urban floods, and wildfires. It has a moderate risk of experiencing earthquakes, water shortages, and extreme heat, with a low to extremely low risk of landslides, coastal floods, and storms. For Bulgaria, floods are the most common natural disaster with an annual impact on 80000 people and an average GDP of $400 million. Areas along major rivers are most exposed to flooding risk, although the provinces of Jambol, Pazardzhik, and Plovdiv have the highest flood risks. Recent modeling work estimates that floods that occur once every 50 years (with a probability of 2% occurring every 50 years) may affect GDP of $2 billion. Based on different climate change and socio-economic predictions, GDP may double or quadruple by the 2080s (Republic of Bulgaria, 2018). There is a significant risk of natural disasters in the Black Sea coastal areas of Bulgaria, including geophysical dynamics and seismic activity, as well as earthquakes. Landslide activity is frequent in most areas of the northern coast, exacerbated by rainfall, earthquakes, and declining groundwater levels.

3.2 Key climate hazards and disasters in Bulgarian rural area

3.2.1 Spatial distribution of meteorological events and climate events in Bulgaria

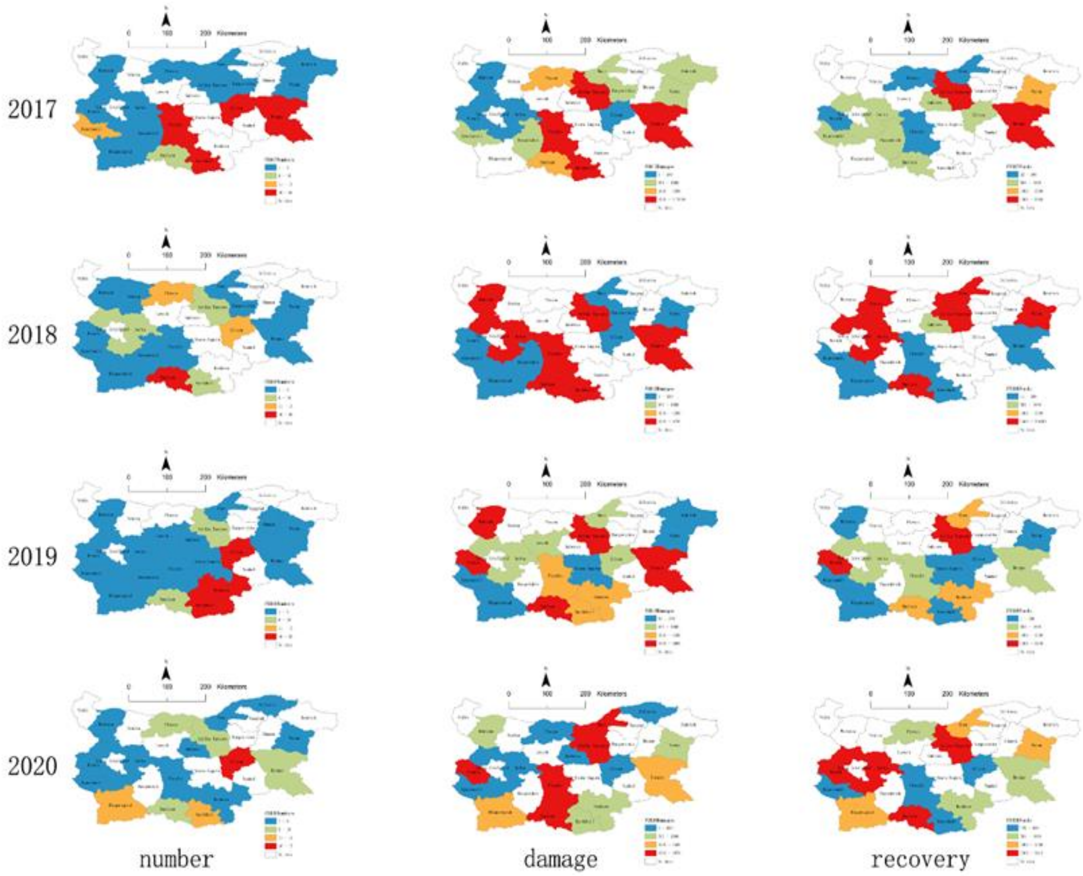


Figure 3-1 Floods for the period 2017 - 2020

The number of floods, compensation for losses and post disaster reconstruction funds, the losses from disasters have shown a decrease from 2017 to 2020. The main economic losses caused by flood disasters being in Plovdiv and its surrounding areas.

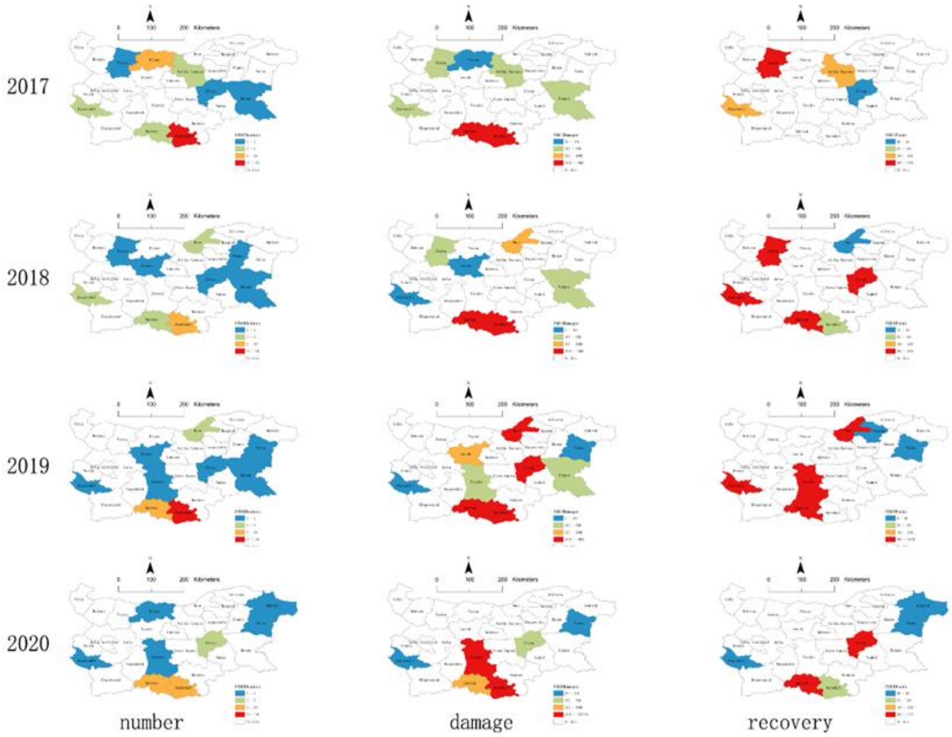


Figure 3-2 Landslide for the period 2017 - 2020

The number of landslide disasters, loss compensation, and post disaster reconstruction funds have shown a decrease from 2017 to 2020. The main areas of landslide disaster losses are Plovdiv, Smolyan, Kardzhali, and other areas.

3.2.2 Spatial distribution of meteorological events and climate events in Bulgaria

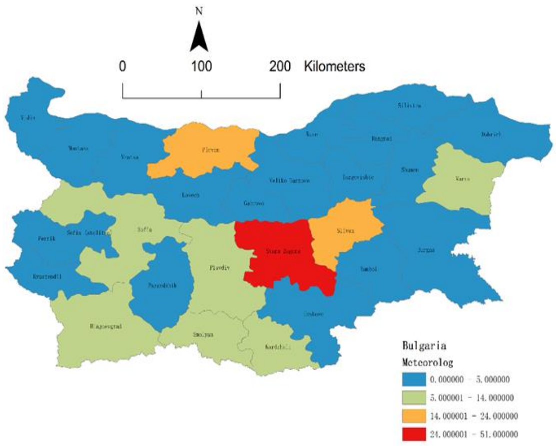


Figure3-3 Number of meteorological events occurred by districts in 2021

We conducted a statistical analysis of the number of meteorological disasters in Bulgaria in 2021. Meteorological disasters include storm, extreme winter conditions, fog. Quantitative analysis of meteorological disasters in 2021 revealed that Stara Zagora has the highest number of disasters.

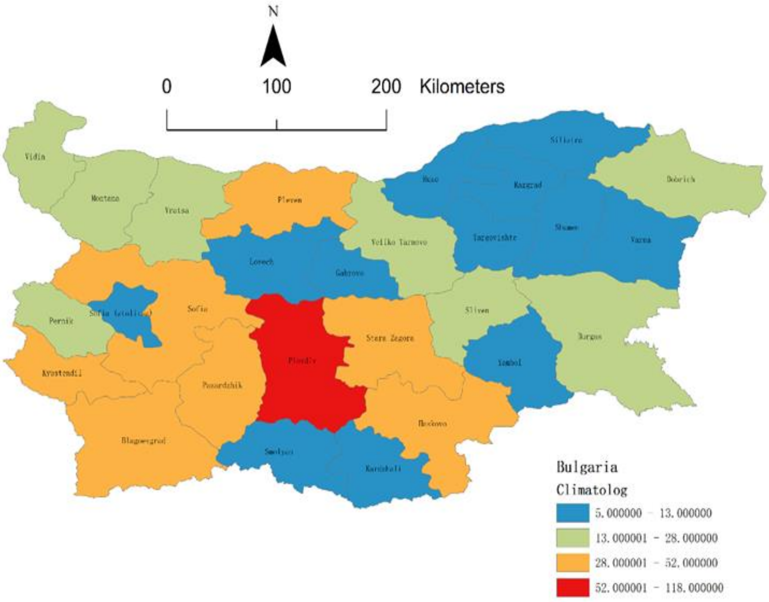


Figure3-4 Number of climatological events occurred by districts in 2021

We conducted a quantitative analysis of climate events in 2021. Climatological events Include： drought, forest fire, field fire. We found that Plovdiv is the region with the highest number of climate events.

3.3 Impacts of climate hazards and disasters in Bulgarian rural area

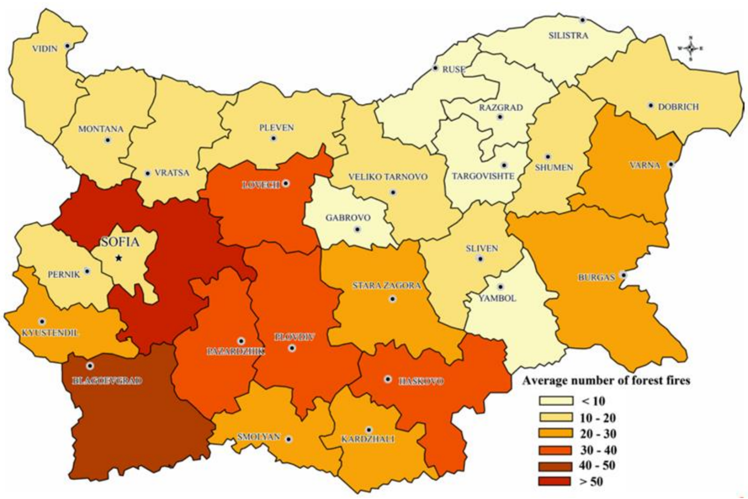


Figure 3-5. Average number of forest fires in Bulgaria by administrative districts (2000–2021) (Nojarov and Nikolova, 2022)

The threat of forest fires in Bulgaria is relatively high. The analysis of the conditions for the occurrence of forest fires was carried out on the basis of data on forest fires from 2000 to 2021. During this period, a total of 12,036 wildfires occurred, or 573 fires on average per year. The highest average number of forest fires was observed in southwestern Bulgaria, including the districts of Sofia-oblast (54) and Blagoevgrad (44). But the smallest average number of fires was observed in northeastern Bulgaria, in the districts of Targovishte (3), Razgrad (5), Ruse (6), and Silistra (8) (Nojarov and Nikolova, 2022).

There was no significant trend in the average maximum temperature of heat waves between 1979 and 2021 (except for southwestern Bulgaria). This is due to changes in the atmospheric circulation over Bulgaria in the 21st century, resulting in an increase in summer air mass transport from the northeast. The heatwave has had a significant impact on Bulgaria's summer forest fires. More, longer, and hotter heat waves provide more favorable conditions for the occurrence and development of forest fires.

Climate change is expected to increase the frequency and scale of extreme weather events in the region, including extreme precipitation and temperature, storms, floods, wildfires, landslides, and droughts. The main dangers facing Bulgaria include floods, droughts, extreme heat, wildfires, storms, earthquakes, and landslides. The expected increase in temperature may exacerbate the existing risks of temperature related hazards such as heatwaves, droughts, and fires. The prediction estimates that due to rising temperatures and changes in rainfall, the risk of wildfires increases and the fire season extends. Changes in temperature and precipitation may also affect soil fertility, further affecting the food system. Although the mortality rate caused by low temperatures is expected to decrease, high temperatures, increased heat wave risks, and drought may have an impact on temperature related mortality rates.

Climate change is expected to affect the reduction of water volume in the country's major rivers, thereby affecting the availability of water resources. In addition to changes in precipitation, changes in regional hydrology may also be related to the risk of extreme events such as drought and floods. The changes in regional precipitation are expected to affect the existing river flow patterns by increasing peak flow in major catchment areas such as the Danube River on the northern border of Bulgaria. Bulgaria is known for its diverse and fertile soil, which is susceptible to erosion caused by changes in precipitation patterns, which has raised concerns among governments that prioritize agricultural production. The tourism industry is an important contributor to GDP and is also sensitive to changes in climate and tourism infrastructure in coastal areas.

4. Impacts of climate change to key sectors

4.1 Agriculture

4.1.1 Overview

Bulgarian agriculture plays an essential role in the national economy. Although the sector's share in the generated gross value added (GVA) is declining, agriculture is considered a main source of income and employment in rural areas, especially in North Bulgaria.

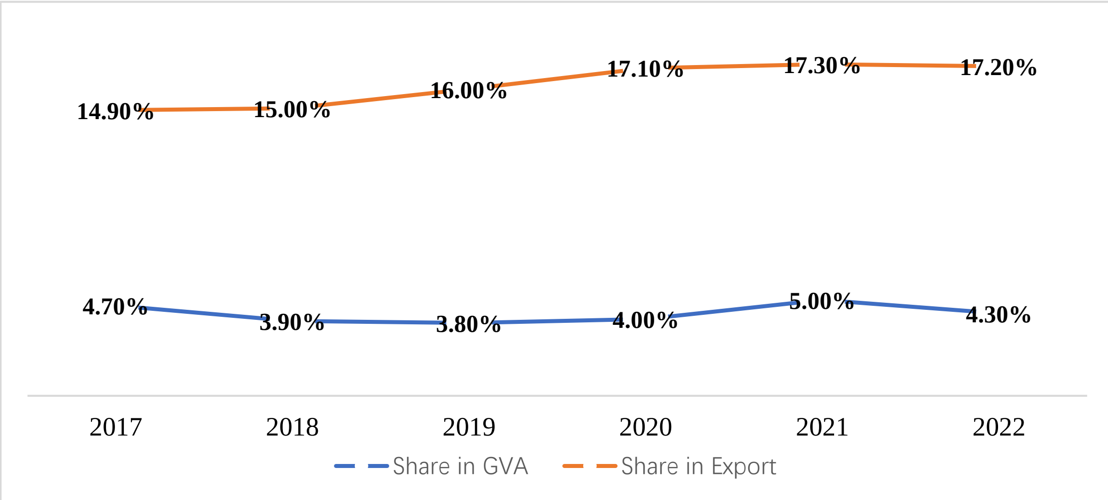
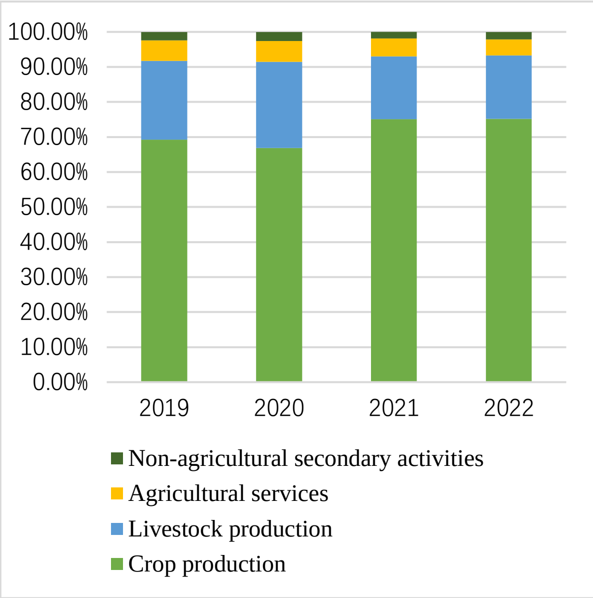


Figure 4-1 Role of agriculture in Bulgarian economy (Source: National Statistical Institute, Ministry of Agriculture and Food)

The decreased share of agriculture in the national economy, a trend in EU-27 and developed countries is a positive phenomenon only when an increase in the volume and quality of agricultural production accompanies it. In the country, however, there is a decrease in production and challenges related to competitiveness. Therefore, the downward rate of change in GVA is a sign of structural and production issues.



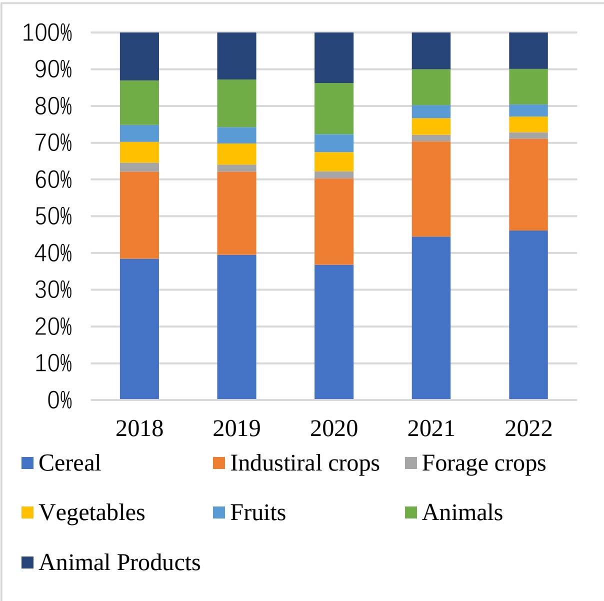


Figure 4-2: Structure of agricultural gross production (%) (Source: National Statistical Institute, Ministry of Agriculture and Food)

Bulgaria's agricultural output is dominated by crop production. Since the accession to the EU, livestock production in Bulgaria has shown a significant decrease. Cereals, especially wheat, maize and sunflower, accounted for a significant share of agricultural output. The data shows that the role of cereals and industrial crops is increasing.

Bulgaria has undergone a structural transformation in agricultural holdings. The total number of farms in Bulgaria declined by more than 80% for 2003-2020. On the other hand, the average size of the farms increased more than eight times.

Table 4-1: Trends in the number of agricultural holdings (Source: Ministry of Agriculture and Food, Farm Structure Survey)

Indicators	**2003**	**2005**	**2007**	**2010**	**2013**	**2016**	**2020**
Number of holdings	665548	534613	493133	370222	254142	201014	132742
Average size (ha)	4.4	5.2	6.3	10.1	15.5	20.6	33.2

The structural changes are linked to farm concentration, innovations, and the introducing of new technologies and precision farming in cereal production.

A polarized farm structure characterizes the Bulgarian agriculture sector.

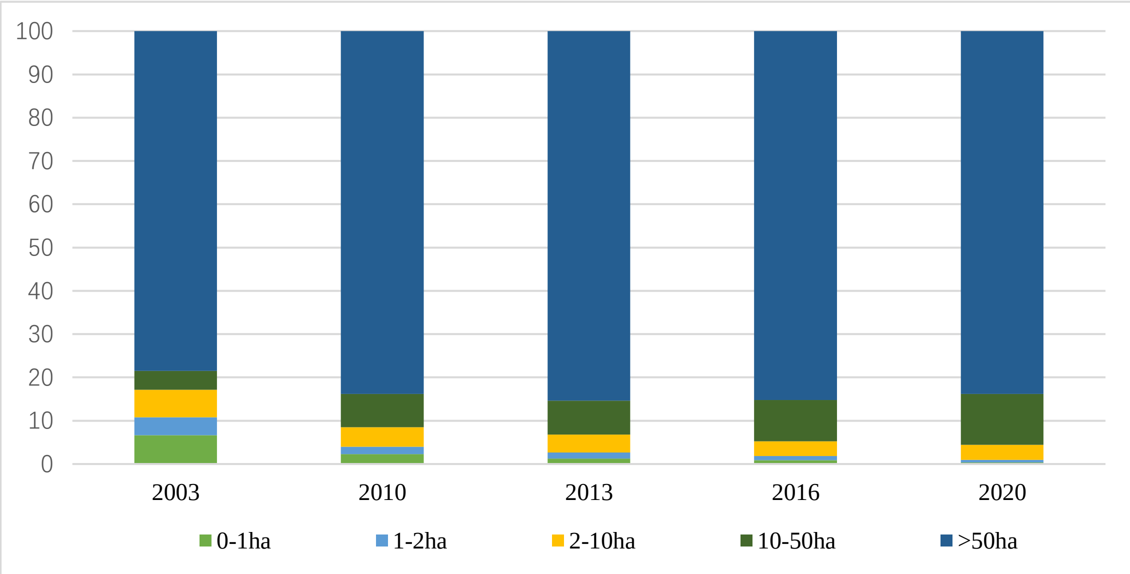


Figure 4-3 Structure of agricultural holdings by farm size (UAA, %) (Source: Ministry of Agriculture and Food, Farm Structure survey)

The share of small agricultural holdings is much higher than the EU-27 average. Small farms are important in terms of employment in rural areas- 47% of all farms are under 2 hectares. On the other hand, these agricultural holdings account for 1% of the utilized agricultural area. By contrast, the accumulated UAA in the large holdings above 50 ha is 80% of the UAA in the country. The analysis of the number of holdings shows that the ongoing transformations after Bulgaria accession to the EU led to an unbalanced agricultural structure.

4.1.2 Climate Change Impacts

According to Word Bank (2021), Bulgaria is located in a region significantly influenced by climate change, such as increased temperatures and precipitation, extreme weather, floods, and droughts. These events have a serious impact on agriculture and the national economy.

Bulgaria is a relatively small country in terms of area. However, it has a complex climate profile with five zones: moderate continental, intermediate, continental Mediterranean, maritime, and mountainous (UNFCCC, 2014).

Bulgaria has been undergoing a consistent warming trend since the late 1970s. Approximately 20 out of 23 years spanning from 1989 to 2011 displayed notably higher average temperatures compared to the baseline period of 1961 to 1990, tendencies similarly observed between 2000 and 2014. From 1988 to 2014, the average annual air temperature (within areas up to 800 meters in altitude) increased by 0.8°C in contrast to the reference average for the climatic period of 1961 to 1990, fluctuating from 10.6°C to 13.0°C. Notably, temperature anomalies for all years post-2007 (excluding 2011) recorded deviations surpassing +1°C.

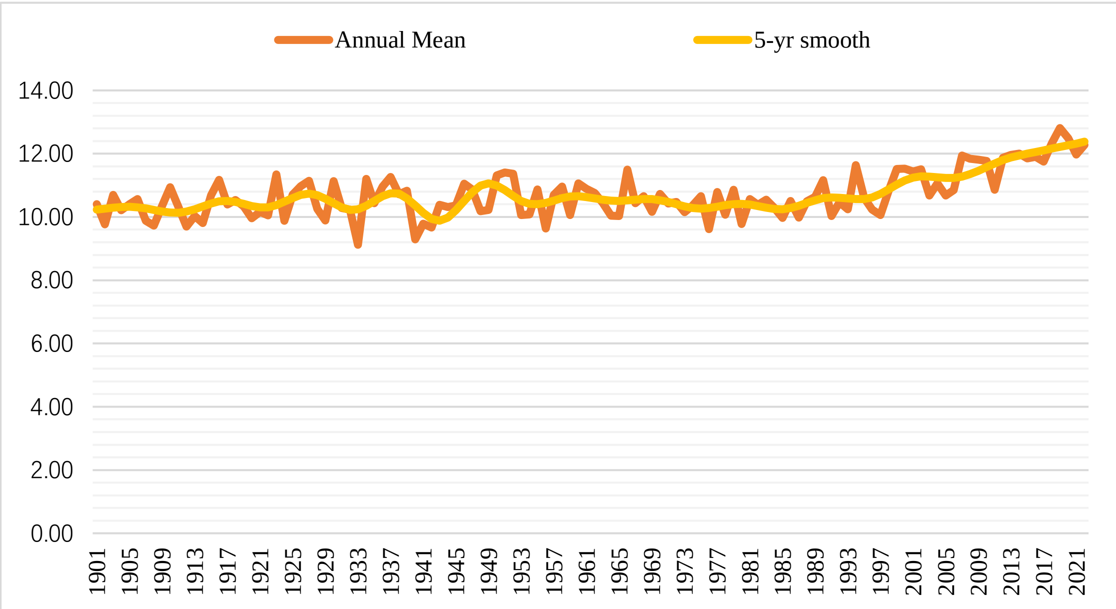


Figure 4-4 Average Mean Surface Air Temperature (1901-2022) (Source: Word Bank Climate Change Knowledge Portal)

Over the past decade, Bulgaria's weather patterns have been characterized by substantial fluctuations in seasonal temperatures. Two prolonged heatwaves were documented in 2007 and 2011, affecting southwestern and northern Bulgaria, where temperatures soared to absolute maximum values ranging between 38°C and 40°C. Notably, January 2017 marked Sofia's coldest month in the past 53 years, accompanied by temperatures dropping below minus 20°C in various regions throughout the country. (ICPDR, 2015). Deviation for 2022-2023 by months compared to 1961-1990 is 1.7 °C.

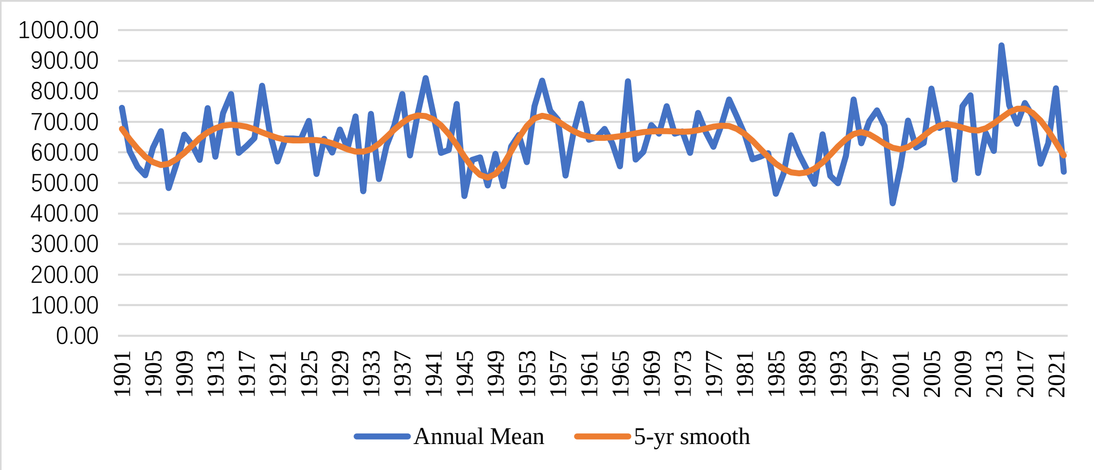


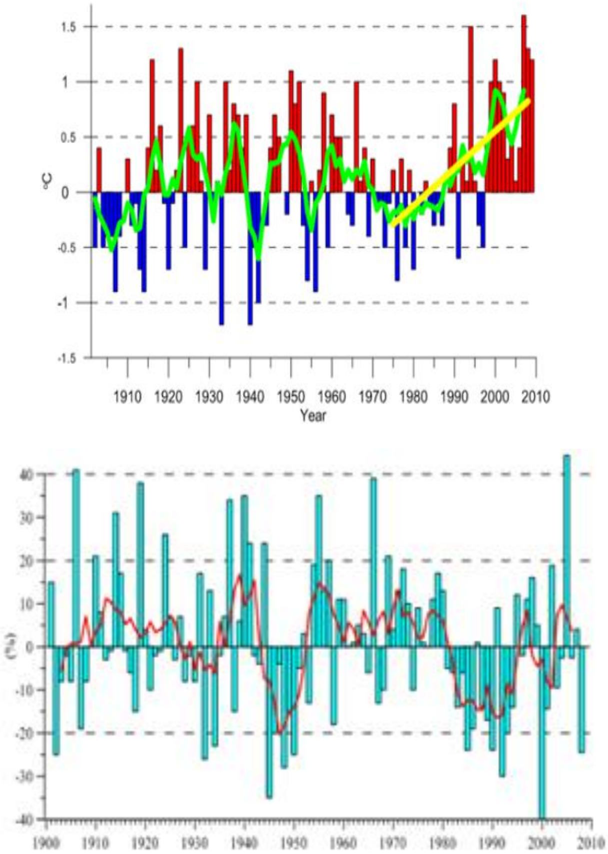
Figure 4-5 Observed annual precipitation(1901-2022) (Source: Word Bank Climate Change Knowledge Portal)

According to the data, there has been a serious increase in average precipitation levels in the past two decades. Between 1988 and 2014, Bulgaria experienced an average annual precipitation ranging from 377 mm to 1,013 mm. Notably, the average number of days with overnight precipitation exceeding 100 mm showed a significant rise, approximately 30 %, from 1991 to 2007 when contrasted with the baseline from 1961 to 1990. Moreover, the meteorological network recorded a higher frequency of heavy rainfall occurrences. Uncommonly associated with winter months such as January and February, cloudiness, thunderstorms, and hailstorms became more frequent.

Between 1988 and 2014, the average annual rainfall stood at 166 % of the baseline norm recorded from 1961 to 1990.

Throughout the past century, Bulgaria experienced three distinct periods of drought: 1902–1913, 1942–1953, and 1982–1994. The drought persisted through 1990, resulting in dwindling river discharge rates and substantial drops in water levels within multiyear reservoirs. Remarkably, 1993, 1994, and 2000 were recorded as the driest in Bulgaria's history.

The droughts in 2000, 2007, and 2012 significantly reduced Bulgaria's average maize grain yield to less than 1.8 tons per hectare (Popova et al., 2014).



Note: Bars measure monthly precipitation anomalies compared with period 1961–1990; red line measures moving average.

Figure 4-6 Anomalies of Annual Temperature (left) and Historic Mean Annual Precipitation in Bulgaria (right), relative to 1961–1990 (Source: UNFCCC, 2014)

A defining characteristic of Bulgaria's agro-climatic conditions is water scarcity. While meteorological drought pertains to the duration and severity of dry periods, agricultural drought links various aspects of meteorological or hydrological drought to agricultural impacts. It specifically addresses issues such as soil water deficits, insufficient precipitation, disparities between actual and potential evapotranspiration, as well as diminished groundwater or reservoir levels.

Bulgaria is facing an escalated frequency of flood occurrences. Between 1991 and 2007, there was a 30 % rise in the average number of days featuring precipitation exceeding 100 mm compared to the baseline of 1961 to 1990. According to the

UNFCCC statistics, specific regions experienced precipitation within a few hours, equaling the typical amount expected over three months. The increased incidence of intense, short-duration heavy rainstorms contributes to amplified short-term surface runoff and heightens the risk of soil erosion, particularly in areas with more vulnerable soil types and sloping terrains.

According to GFDRR, in Bulgaria river flood, urban flood, landslide, and wildfire hazards are classified as high. In addition, water scarcity and extreme heat hazards are characterized as medium.

Higher temperatures affect crop yield, water shortages, stress on animals, new pests, viruses, diseases, loss of crops.

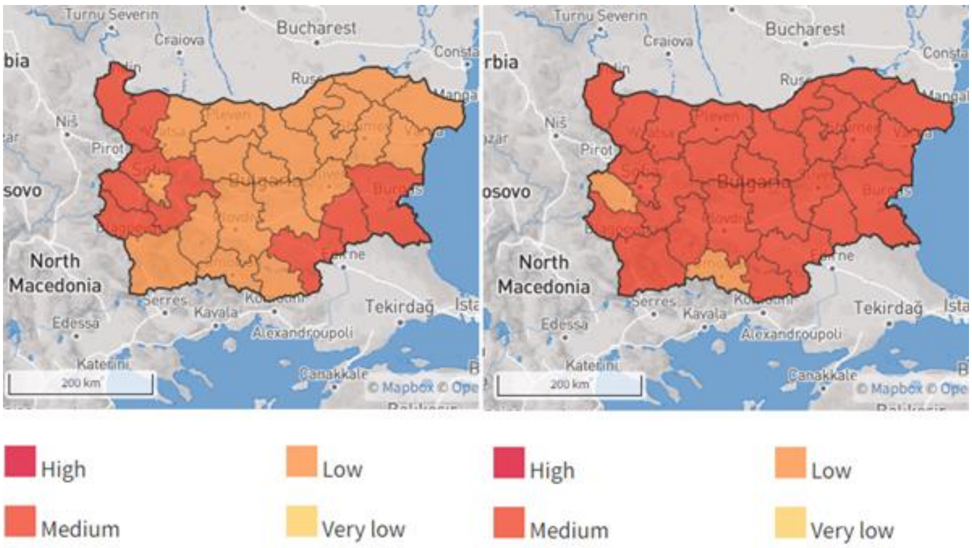


Figure 4-7 Water scarcity (left) and extreme heat (right) hazards (Source: GFDRR)

Based on the National Climate Change Adaptation Strategy and Action Plan, the main effect of the abovementioned climate change trends on Bulgarian agriculture can be divided into (***1) Climate change impact on crop productivity, (2) Climate change impact on livestock; (3) Pests, diseases and weeds (4) Impact on natural resources.***

(1) Climate change impact on crop productivity

Weather conditions play an important role in determining agricultural crop productivity. Extreme weather events and climate variations significantly impact yields and can potentially negatively affect agricultural output and food security.

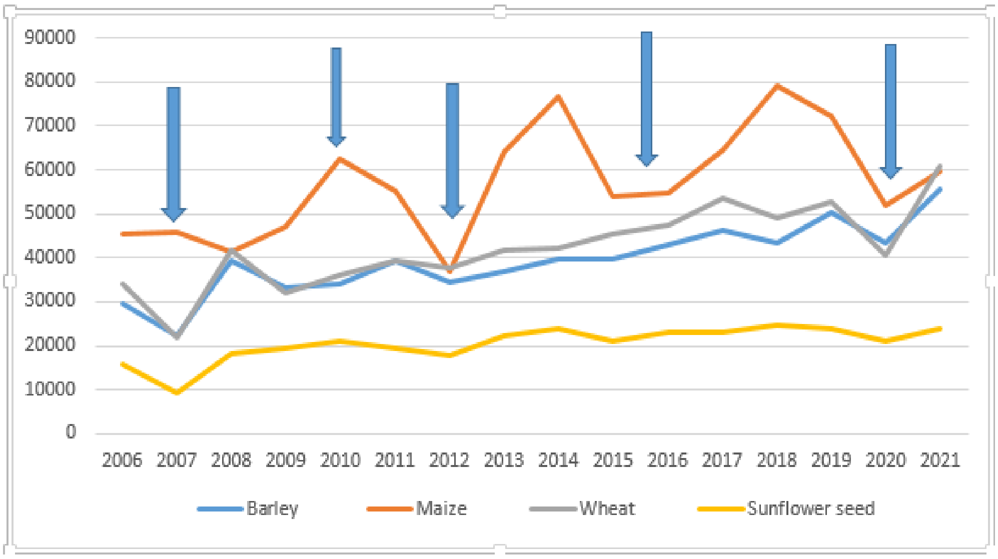


Figure 4-8 Main crop yields (100 g/ha) (Source: FAOSTAT)

The anticipated rise in CO[2] concentration might provide conditions that will increase the yields of main crops. On the other hand, this potential growth could face obstacles due to drought risks and a shorter reproductive period caused by rising air temperatures. Consequently, there may be a shift in crop maturity dates, growing period alterations, and crop yield fluctuations.

The data for 2007-2022 shows the negative impact of droughts on average yields for crucial Bulgaria crops such as wheat, maize, barley and sunflower. Based on the results, it can be concluded that the temperature increase may hinder vernalization in winter cereals.

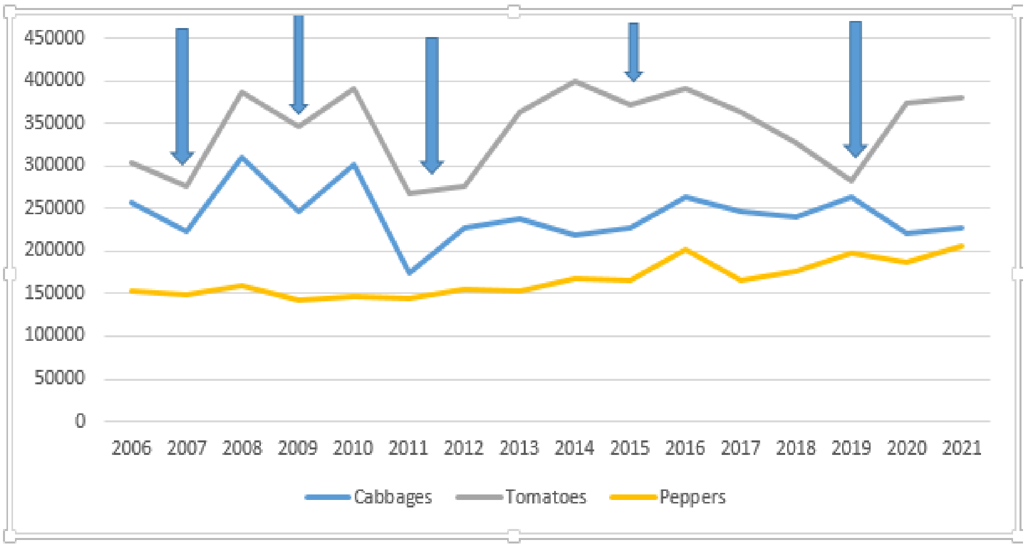


Figure 4-9 Vegetable yields (100 g/ha) (Source: FAOSTAT)

Vegetables are also affected by droughts because they limit the availability of water resources. These main crops decreased average yields due to water shortages during the 2009, 2011, and 2012,2015,2020 droughts. Another important factor that is a major challenge for the sector is the old irrigation infrastructure and the decline in the irrigation area.

Climate change can also affect the length of the growing season. In this regard, the longer growing season can positively impact thermophilic species and ensure better irrigation opportunities and conditions for crop growth, development, and productivity. In addition, climate change can lead to the potential expansion of new varieties in North Bulgaria and mountainous areas. On the other hand, a longer growing season can cause the spread of weeds, diseases, and pests.

Changes in the occurrence dates of phenological phases, specifically earlier fruit plants flowering or ripening, are monitored in European countries (IPCC, 2013). In Bulgaria, these processes can lead to changes in natural crop cycles. In the fruit sector, these changes can positively impact productivity; however, regarding cereals, the shorter reproductive period can negatively affect yields.

2) Climate change impact on livestock

Increased temperatures have adverse effects on livestock. It most directly affects the health and welfare of animals. The expected temperature increase would impact the mountainous regions more than the rest of the country, especially the lowlands, where the animals are better adapted to the temperature variations.

In general, higher temperatures can also decline the reproductive capacity of animals, with reduced fertility in dairy cattle and sows.

In addition, climate change may lead to the development of pathogens and parasites, as a result of which we may have an increase in mortality or additional costs for medicines and a decrease in economic results.

Fodder crops are also affected by global warming. A decline in their yields and quality will affect animal husbandry and the profitability of the farms.

Longer dry periods may reduce groundwater and affect water supply. Scarcity of water resources can affect the livestock. In addition, drought would affect pasture areas and, hence, animal nutrition. Therefore, due to climate change, less pasture at certain times of the year could lead to overgrazing and erosion risks in these regions.

Based on that, it can be concluded that climate change can affect the food security and nutrition of the population.

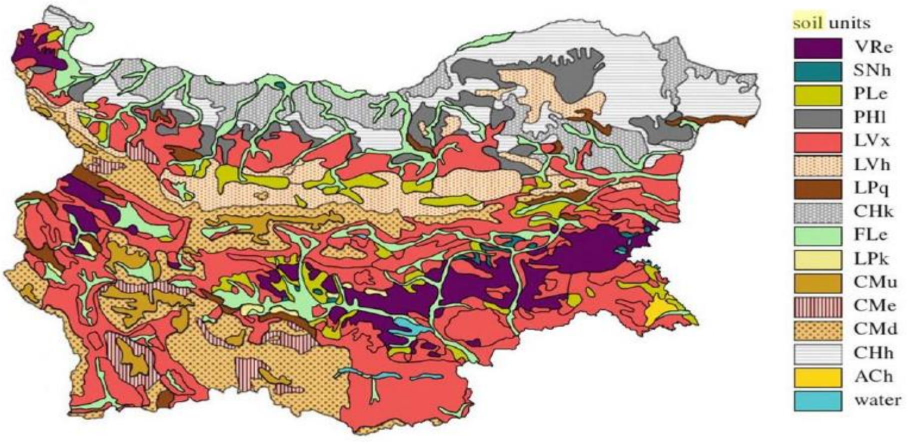
(2) Pests, diseases and weeds

Climate change could increase the spread of many weeds, diseases and pests in agriculture. Temperature and moisture changes can lead to different interactions between pests and their natural enemies and hosts. There are 347 alien terrestrial arthropods in Bulgaria, of which 52 species are crop pests with a negative impact on agriculture (UNECE, 2017). The increased temperatures can shorten the reproductive cycle of many pests, increasing the risk to crops. Based on that, there will be a need for increased use of pesticides and herbicides that would affect crops and human health. Climate change can stimulate the development of toxigenic micro-fungi and easily contaminate crops like wheat and maize. In addition, a longer growing season would create favorable conditions for increasing the number of generations of pests. Climate change can lead to the spread of new for the region pests, diseases and weeds.

(3) Impact on natural resources

Soil types, soil erosion, desertification, and salinization

Bulgaria has different types of soils, and fertile Chernozems occupy 21% of the country's territory. In addition, other soil types have an important role in developing vegetable production.



FAO Classification	*Code*	*FAO Classification*	*Code*
Eutric Vertisoils	Vre	Eutric Fluvisols	Fle
Haplic Solonetzs	SNh	Rendzic Leptosols	PLk
Eutric Planosols	Ple	Humic Cambisols	Cmu
Kuvic Phaeozems	PHI	Eutric Cambisols	Cme
Chomic Luvisols	LVx	Dystric Cambisols	CMd
Haplic Luvisols	LVh	Haplic Chernozems	CHh
Lithic Leptosols	LPq	Haplic Acrisols	Ach
Calcic Chernozems	CHk		

Figure 4-10 Spatial Distribution of Soil Formations in Bulgaria (Source: Shishkov T. and Kolev N. 2014.)

Most soil types do not have a high natural resistance to deteriorating physical conditions such as high temperatures or intense rainfall. Particularly vulnerable are regions in South-Eastern Bulgaria, which have lower amounts of precipitation during the warm half-year event. (Shishkov, Kolev,2014). As a result of the above-mentioned, it can be concluded that climate change will lead to lower soil fertility.

Droughts and winds will increase erosion and soil degradation. This may result in desertification and an increase in the share of abandoned land. Such processes will have a negative impact on agricultural production and yields.

About 65 % of arable land is threatened by varying water erosion. In addition, 24 % is threatened by wind erosion. The average annual intensity of soil erosion varies by land use, but soil losses for agricultural land are estimated at 12,256 tonnes/ha (Ministry of Environment and Water, 2015) per year. About 35,500 ha of arable land (Ministry of Environment and Water, 2014) have been identified as affected by salinization processes. Overall, climate change will significantly affect future land use.

Water scarcity and shortages

Climate change can lead to water scarcity, which has a direct impact on irrigation. This process will influence the production capability of a number of crops. Trends predicting continued droughts and extreme heat will lead to competition for irrigation and water use in agricultural production, affecting crop production stability.

4.2 Forestry

4.2.1 Overview

The Bulgarian government recognizes forestry as a priority sector in addressing climate change, not only because forests cover more than one-third of the country, but also because forests contribute to economic growth, provide ecosystem services, and support disaster risk management. Bulgaria's total forest area is 4.2 million hectares, contributing approximately 500 million euros to the economy annually, including 43000 jobs in the forest sector. In areas with high forest coverage, the forestry sector is the most important economic activity. In the past 50 years, the forest area has increased by 500000 hectares and the forest stand area has doubled, mainly due to afforestation and land use shifting from farmland to forests (Republic of Bulgaria, 2017, 2018).

The average age of forests in Bulgaria is 57 years old. In the context of erosion control, forest health is also important because forests support land protection and soil health, with approximately 39.8% of forests considered to have a protective or restorative effect. The state manages 74.5% of the forest, while municipal governments, private individuals, and religious groups manage the remaining 25.5% of the forest. The majority of forests are deciduous forests (69.5%) and coniferous forests (30.5%), with a total volume of approximately 680 million cubic meters, of which the majority are deciduous forests, accounting for 55.4%. The average annual timber harvest is 14 million cubic meters. The government's forest strategy focuses on ensuring the sustainable use of forest resources, strengthening the role of forests in supporting economic growth and socio-economic development, and increasing their contribution to the green economy.

4.2.2 Climate Change Impacts

Changes in precipitation and the occurrence of more extreme weather events may have long-lasting impacts on forest health. Attempts to calculate degradation estimated that Bulgaria lost 25.2% of its ecosystem value due to degradation in 2015 (Sutton et al., 2016). Forests help maintain soil health and prevent erosion, but they are also affected by degradation. The trend of rising temperatures has changed the phenolic composition of forests, with the development stage of forests advanced by 7-15 days, leading to an increase in the length of the growing season. However, there is also a high risk of damage caused by late frost or long-term exposure to high temperatures.

The increase in drought risk may also increase stress and lead to high mortality rates in forests. Death outbreaks in forest health are often associated with deteriorating health, making certain forests more susceptible to insect outbreaks and other diseases. The availability of water resources or changes in precipitation distribution increase the likelihood of forest fires. In the past few decades, forest fires have significantly increased, which is closely related to the dry summer years. Most forest fires occur in lowlands, but in dry years, there are also forests in mountainous coniferous forests. Most forests in Bulgaria have an altitude below 800 meters and therefore face a higher risk of heat stress. The decline in forest health also increases the risk of natural disasters such as forest fires, thereby affecting other sectors such as agriculture, health, and energy.

4.3 Water & Energy

4.3.1 Overview

Compared to other European countries, Bulgaria has abundant freshwater resources and more favorable soil and climate conditions. These areas are concentrated in major waterways, river basins, and snow, although only 2% of the areas are covered by fresh water and vary according to season. Water provides important services to the economy as an input for agriculture, a habitat for aquaculture, and participates in domestic consumption and energy production. In 2015, the main economic sectors used 473.5 million cubic meters, of which 86% were used for industry, 8% for agriculture, 5% for private household consumption, and 1% for the service industry. The country has up to 21.3 km^3 of long-term annual renewable water resources, most of which come from surface water compared to groundwater resources. Despite abundant water resources, in 2016, 10.7% of the population had no basic sanitation facilities, compared to 1.9% in Europe. The quality of wastewater management has significantly improved; However, the biochemical oxygen demand in rivers continues to be higher than the European average (2.86 milligrams of oxygen per liter in Bulgaria and 2.19 milligrams of oxygen per liter in Europe). It is estimated that 86% of the population has improved sanitation facilities, although 14% of the population shares sanitation facilities (Eurostat, 2018; UNICEF, 2018).

Bulgaria has a total primary energy supply of 18.6 Mtoe, of which 12.1 Mtoe are produced locally and 6.9 Mtoe are imported (Republic of Bulgaria, 2019). The country consumes approximately 34.87 megawatt hours per year, with a per capita consumption of 4.86 megawatt hours per person. Compared to Europe, Bulgaria has a lower energy dependence, with 37.2% of its energy imports, while the average level in Europe is 53.6% (International Energy Agency Statistics, 2015). Although the vast majority of the population has access to electricity, it is estimated that 36.5% of the population cannot maintain sufficient warmth in their homes during winter. Fossil fuels provide most of Bulgaria's energy, particularly coal (33.8%), oil (21.7%), and natural gas (13.3%). However, energy also comes from nuclear energy (2.5%), biofuels/waste (6.3%), hydrology (2.5%), and other renewable energy sources (1.7%). Most renewable energy comes from hydroelectric power resources and is susceptible to the impact of climate change (Eurostat, 2018).

4.3.2 Climate Change Impacts

For water, climate change not only affects precipitation, but also affects river hydrology and soil moisture levels. Seasonal and flow changes may lead to hydrological and meteorological disasters such as floods and droughts; In some river basins, the emission rate is expected to decrease by 10% over the next 30 years compared to the levels from 1976 to 2005. In recent years, evidence of natural disasters has shown that there is a significant risk of river floods and droughts occurring. As shown in the future climate simulation section, areas that heavily rely on surface water are more susceptible to drought compared to areas that use groundwater. Some predictions predict that the southeastern and northwestern regions of the country have the highest risk of long-term water scarcity. In high emission scenarios, it is expected that by the 1990s, the likelihood of severe annual drought will change from less than 21% to 40% -90%. In the short term, areas near rivers may experience vulnerability, and flow fluctuations in these areas may increase. Natural systems may also face challenges due to the lack of wastewater management, which can exacerbate this situation in extreme events and increase the demand for agricultural inputs (fertilizers and pesticides), which may lead to runoff pollution. Freshwater extraction used for energy production accounts for 65.3% of the extracted water demand (5.629 billion m3 in 2015), which is the main reason for increasing water demand. If water becomes scarce or highly variable, critical infrastructure such as hydroelectric power plants, nuclear power plants, and sanitation facilities that currently require a large amount of water may also be affected, which rely on reliable water flow.

For energy, climate change is expected to increase the pressure on existing energy infrastructure. Most power generation methods require a large amount of water for cooling, which has a particularly strong impact on nuclear power generation. Hydrological changes may lead to water scarcity and changes, thereby affecting energy production. Energy production may also face the risk of pressure from floods and rising temperatures, depending on their location in the country. Rising temperatures will increase energy demand and also put pressure on energy production infrastructure. Climate prediction predicts that due to adaptation to temperature rise behavior (i.e. the use of air conditioning and fans), the number of days requiring cooling will mainly increase during the summer months of June to September. As the temperature rises, the demand for winter heating fuel may also decrease with the decrease of heating days. The future of obtaining renewable energy through hydroelectric power generation is uncertain, considering the expected changes and the height changes of river flow across years.

5. Climate adaption policy

"Institutional frameworks, policies and instruments that set clear adaptation goals and define responsibilities and commitments and that are coordinated amongst actors and governance levels, strengthen and sustain adaptation actions (very high confidence)."

(IPCC, Summary for policy makers, 2022)

5.1 Policy framework for climate adaptation in rural area

The adaptation is the only available and appropriate response to the changing climate even if all new CO2 emissions are halted today (IPCC, 2022; EU Climate Adaptation Strategy, 2021). The IPCC report pointed out that the key enabling conditions for adaptation were "political commitment, institutional frameworks, policies and instruments with clear goals and priorities, enhanced knowledge on impacts and solutions, mobilization of and access to adequate financial resources, monitoring and evaluation, and inclusive governance processes" (IPCC, 2022).

The 2022 IPCC Summary for policy makers also warned against maladaptation practices. They included actions that focused on sectors and risks in isolation and on short-term gains. The implementation of maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change. The examples given included hard defences against flooding; which reduce space for natural processes and represent a severe form of maladaptation for the ecosystems they degrade, replace or fragment, thereby reducing their resilience to climate change and the ability to provide ecosystem services for adaptation.

5.1.1. The global policy framework for adaptation

The UN Framework Convention on Climate Change (UNFCCC, 1992) treated mitigation and adaptation as being equally important. Article 3 positioned adaptation as one of the policies and measures to mitigate the adverse effects of climate change (Art. 3(3)). However, for over two decades the global efforts were focused on mitigation with significantly less attention on adaptation. Verschuuren underlined that the unbalanced focus was valid not only "for the policy and legal measures taken on the basis of the UNFCCC, but also for academic research" (Verschuuren, 2022).

The 2015 Paris Agreement stressed that adaptation is equally important as mitigation, and in fact referred to the necessary balance between mitigation and adaptation in several articles. It set a global goal for adaptation for the first time (Box 1), recognizing that the current need for adaptation is significant, and that greater levels of mitigation can reduce the need for additional adaptation efforts (Art. 7(4)). The need for integrating adaptation into relevant socioeconomic an environmental policies and actions was also stressed (Art.7(5)).

Box 1. Global goal on adaptation, Paris Agreement, Article 7

1. Parties hereby establish the **global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change**, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2 [keeping global average temperature rise limited to between 1.5 and 2 degrees Celsius].

The commitments of the countries parties to the Paris Agreement comprised (Art.7(9)):

- The implementation of adaptation actions, undertakings and/or efforts;
- The process to formulate and implement national adaptation plans;
- The assessment of climate change impacts and vulnerability, with a view to formulating nationally determined prioritized actions, taking into account vulnerable people, places and ecosystems;
- Monitoring and evaluating and learning from adaptation plans, policies, programs and actions; and
- Building the resilience of socioeconomic and ecological systems, including through economic diversification and sustainable management of natural resources.

Six years after the Paris Agreement, at the 26th meeting of the signatories of the UNFCCC (CoP 26) agreed a bi-annual work programme (2022-2023) to support the global goal on adaptation – known as the Glasgow-Sharm el-Sheikh work programme. It had eight main objectives:

(1) Enhancing overall adaptation action and support;

(2) Understanding of the methodologies, indicators, data and metrics, needs and support needed for assessing progress towards it;

(3) Reviewing the overall progress made in achieving the global goal on adaptation;

(4) Enhancing national planning and implementation of adaptation actions;

(5) Better communicating national adaptation priorities, implementation and support needs, plans and actions;

(6) Facilitating the establishment of robust, nationally appropriate systems for monitoring and evaluating adaptation actions;

(7) Strengthening implementation of adaptation actions in vulnerable developing countries;

(8) Improving complementarity and reducing overlapping communication and reporting efforts.

In 2022, the implementation of the Glasgow-Sharm el-Sheikh work programme agreed on a joint implementation work programme focused on food and agriculture for the 2023-2026 period. It emphasized the need to scale up the adaptation action regarding capacity building, access to finance and technology development and transfer for reducing the farmers' vulnerability to climate change. It also highlighted that each food production system had its own challenges and that solutions and policies must be context-specific and take into account national circumstances. The need for stronger collaboration, cooperation and partnerships between public institutions and agencies, the research community, the private sector, civil society and farmers' organizations was also encouraged.

The objectives of the Glasgow-Sharm el-Sheikh 2023-2026 joint work program on food and agriculture (2022) comprised:

a) Promoting a holistic approach to addressing issues related to agriculture and food security, taking into consideration regional, national and local circumstances, in order to deliver a range of multiple benefits, such as adaptation, adaptation co-benefits and mitigation, especially for vulnerable groups, including women, indigenous peoples and small-scale farmers;

(b) Enhancing coherence, synergies, coordination, communication and interaction to facilitate the implementation of actions related to agriculture and food security;

(c) Promoting synergies and strengthening engagement, collaboration and partnerships among national, regional and international organizations and other relevant stakeholders, processes and initiatives, in order to enhance the implementation of climate action related to agriculture and food security;

(d) Providing support and technical advice to partners on climate action in agriculture and food security;

(e) Enhancing research and development on issues related to agriculture and food security and consolidating and sharing related scientific, technological and other information, knowledge (including local and indigenous knowledge), experience, innovations and best practices;

(f) Evaluating progress in implementing and cooperating on climate in agriculture and food security;

(g) Sharing information and knowledge on developing and implementing national climate change policies, plans and strategies, while recognizing country-specific needs and contexts.

The EU welcomed the development of the Joint work program on agriculture and food (Swedish Presidency of the Council of the European Union, March 2023) and proposed that the next four years were used to "enhance the exchange between Parties and stakeholders for more ambitious climate action in agriculture, food systems, food security and nutrition by establishing common ground and knowledge on the state of implementation of those actions in all countries. This should be done by identifying challenges and barriers for enhanced implementation, highlighting best practices and lessons learned as well as identifying potential sources of financial and technical support and exploring how to ensure that financial flows in the sector are consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.” The EU also proposed to organize dedicated workshops on the objectives with specific thematic topic for each workshop. The proposed non-exhaustive list of themes included among others the following themes:

i) Synergies between mitigation, adaptation and biodiversity:

- Improving and restoring ecosystem health and biodiversity, sustainable land management and resilient agroecosystems.
- The role of enhanced carbon removals and their links to increased food security and nutrition in the context of climate change and climate action.
- The role of agroecology including agroforestry in this context.
- The synergistic role of rural women as promoters of sustainability
- How to facilitate the implementation of those mitigation and adaptation measures.

ii) Food systems and climate:

- Options for low emission food systems, incl. agroecology and nature-based solutions.
- Deforestation free production and value chains.
- Meaning of the Global Goal on Adaptation for agriculture, food security and nutrition.
- The contribution of rural women to food systems as food security drivers.

5.1.2. The European policy framework for adaptation

The European Green Deal, published on 11 December 2019, set out a new growth strategy that aimed to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy, where there were no net emissions of greenhouse gases in 2050 and where economic growth was decoupled from resource use. The European Green Deal also aimed to protect, conserve and enhance the Union’s natural capital, and protect the health and well-being of citizens from environment-related risks and impacts. At the same time, this transition must be just and inclusive, leaving no one behind.

The European climate policy framework contributing to the Paris Agreement commitments and implementing the EU Green Deal strategy included the first EU Climate Law (Regulation 2021/1119) and the second[1] EU Climate Adaptation Strategy (COM (2021)82) both adopted in 2021.

The first EU Strategy on Adaptation to Climate Change (2013) provided a framework and mechanisms to improve the preparedness of member states for current and future impacts of climate change. The strategy aimed to enhance the capacity to respond to the impacts of climate change at the local, regional, national, and European level and supports the development of a coherent approach and improved coordination at the EU level. Both agriculture and fisheries were defined as key vulnerable sectors, dependent on the impact of climate change.

The European Climate Law, 2021

The European Climate Law recognizes that adaptation is a key component of the long-term response to climate change and that the adverse effects of climate change can potentially exceed the adaptive capacities of the EU member states (Art.5, European Climate Law). Thus, member states should enhance their adaptive capacity, strengthen resilience and reduce vulnerability (Art.7 of the Paris Agreement) as well as maximize the co-benefits with other policies and legislation.

The European Climate Law underlines that improving climate resilience and adaptive capacities to climate change requires shared efforts by all sectors of the economy and society, as well as policy coherence and consistency in all relevant legislation and policies; and that nature-based solutions can benefit climate change mitigation, adaptation and biodiversity protection.

Both the EU institutions and member states have to ensure that their policies on adaption are coherent, mutually supportive, provide co-benefits for sectoral policies, and work towards better integration of adaptation to climate change in a consistent manner in all policy areas, including relevant socioeconomic and environmental policies and actions, as well as EU external actions (Art.5(3)). They have to focus on

[1] The first EU Strategy on adaptation to climate change is COM(2013)216 final.

the most vulnerable and impacted populations and sectors, and identify shortcomings in consultation with civil society.

Member states have to adopt comprehensive national adaptation strategies and plans based on robust climate change and vulnerability analyses, progress assessments and indicators, and guided by the best available and most recent scientific evidence (Art.5(4)). In their national adaptation strategies, member states have to address the vulnerability of the relevant sectors - agriculture, and of water and food systems, as well as food security, and promote nature-based solutions and ecosystem-based adaptation.

By 30 September 2023, and in every five years, the EU Commission will assess the relevant national measures, and issue recommendations where it finds that a member state's measures are inconsistent with the climate-neutrality objective or inadequate to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change (Art.7). As per this report in 2023, Bulgaria is among the four EU member states that provided only the mandatory information without a long-term adaptation policy (Figure 5-1).

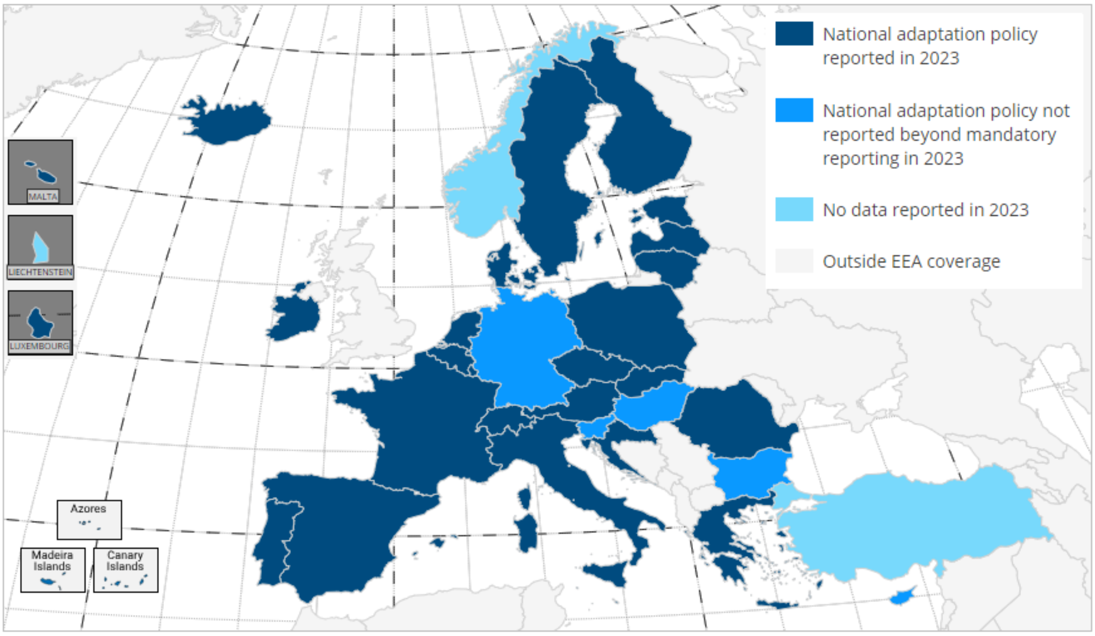


Figure 5-1 Reporting on national adaptation policies in the EU and EEA countries, 2023 **(**Source: https://climate-adapt.eea.europa.eu/en/countries-regions/countries)

The EU Climate Adaptation Strategy, 2021

The new EU Climate Adaptation Strategy accompanies the European Climate Law to step up action across the economy and society towards the 2050 vision for climate resilience, while increasing synergies with other policy areas such as biodiversity. It aims to provide solutions to enable the progress towards the 2050 vision through the following focus areas and actions:

(1) Smarter adaptation: improving knowledge and managing uncertainty

- *Pushing the frontiers of knowledge on adaptation* – Actions: Understand better the interdependencies between climate change, ecosystems, and the services they deliver.

- *More and better climate-related risk and losses data* – To avoid "climate-blind" decisions, data from both the private and public sector should be recorded, collected and shared in a comprehensive and harmonised way. The Commission will facilitate access to climate-related risk and losses data for stakeholders.

- *Making Climate-ADAPT the authoritative European platform for adaptation* – Climate knowledge platforms play an increasing role in decision-making for adaptation action.

(2) More systemic adaptation: Support policy development at all levels and sectors

- *Improving adaptation strategies and plans* – Adaptation strategies at all levels must be effective and based on the latest science. Monitoring, reporting and evaluation are essential to setting a robust baseline against which to measure progress on adaptation. Policy coherence must systematically take into account adaptation to avoid inadvertently undermining it.

- *Fostering local, individual, and just resilience* – The local level is the basis of adaptation, so EU support must help increase local resilience. The EU and Global Covenant of Mayors will be strengthened to assist local and regional authorities. Achieving resilience in a just and fair way is essential so that the benefits of climate adaptation are widely and equitably shared.

- *Integrating climate resilience in national fiscal frameworks* – National fiscal frameworks in the EU include climate change and natural disaster fiscal risks only to a limited extent. Macro-fiscal resilience requires factoring the range of plausible climate scenarios into economic policies and an understanding of disaster risk management.
- *Promoting nature-based solutions for adaptation* – Implementing nature-based solutions on a larger scale would increase climate resilience and contribute to multiple Green Deal objectives. Europe needs to leverage more investments in nature-based solutions to generate gains for adaptation, mitigation, disaster risk reduction, biodiversity, and health.

(3) Faster adaptation: Speeding up adaptation across the board

To accelerate adaptation action, implementation requires resources that are commensurate with the challenge.

- *Accelerating the rollout of adaptation solutions* – The lack of access to actionable solutions is one of the main barriers to adaptation. **Solutions are urgently needed to help farmers and land managers tackle climate risks.** Climate resilience decision support systems and technical advice must become more accessible and rapid to foster their take-up.
- *Reducing climate-related risk* – Investing in resilient, climate-proof infrastructure pays off. Climate adaptation action must better leverage synergies with broader work on disaster risk prevention and reduction.
- *Closing the climate protection gap* – The climate protection gap is the share of non-insured economic losses caused by climate-related disasters. Using insurance as a risk-transfer mechanism to absorb financial losses related to climate risks can be a first step from crisis reaction towards risk management and anticipation. Dialogue and innovation can greatly increase the climate resilience potential of insurance regimes.
- *Ensuring the availability and sustainability of freshwater* – Ensuring that freshwater is available in a sustainable manner is fundamental for climate resilience. EU needs to sharply reduce water use. Climate change also threatens water quality.

5.1.3. The Bulgarian policy framework for adaptation

The Bulgarian policy framework on climate change adaptation is comprised of the Climate Change Mitigation Law (adopted in 2014), the Climate Change Adaptation Strategy and Action Plan (adopted in 2019) and the Long-term Strategy for Climate Change Mitigation towards 2050 (adopted in October 2022). The 2050 Long-term Strategy refers to Bulgaria's international commitments under the 2015 Paris Agreement, the 2021 European Climate Law and 2021 European Climate Adaptation Strategy. However, as the names of the strategic documents indicate they are primarily focused on climate change mitigation.

Bulgarian Climate Change Mitigation Law, 2014

The Climate Change Mitigation Law was adopted in 2014 and amended several times since then, with the latest amendments in October 2023. Its main focus is on mitigation actions and emissions trading and reporting. There only a few references to climate change adaptation, but still important ones. The law aims to ensure the long-term planning of the climate adaptation measures (Art.2) and delegates the responsibilities for sector specific adaptation measures to the respective sectoral ministers (Art.4(1.5)) with the support of the minister of environment (Art.6(2)). The overall responsibility for the development of a national climate adaptation strategy remains with the minister of environment with the support of the sectoral ministers (Art.9(1)). Furthermore, the income from the emissions trading can be used for the development and implementation of climate adaptation measures (Art.23(2)).

It has to be noted that despite the very recent amendment of the Law it does not transpose the European Climate Law in the Bulgarian legislation. This is considered a major weakness and risk of non-implementation of the European climate legislation. Other weaknesses of the law include the lack of science-based and participatory climate governance approaches (Peev, 2022).

Bulgarian Climate Change Adaptation Strategy and Action Plan, 2019

The Bulgarian climate adaptation strategy was adopted in 2019 and thus was based on the first EU climate adaptation strategy from 2013. Although, it is not yet updated to reflect the 2021 European Climate Law or the 2021 European Climate Adaptation

Strategy, it provided a thorough risks and vulnerability analysis per sector and between sectors – agriculture, biodiversity and ecosystem services, energy, forestry, human health, tourism, transport, urban environment, and water and disaster risk management.

There were four general strategic objectives, which were also refered to in the 2022 Long-term Strategy for Climate Change Mitigation towards 2050:

- **Mainstream and integrate climate change adaptation** by strengthening the policy and legal framework for adaptation and the integration of adaptation considerations into existing national and sectoral plans and programs.
- **Build institutional capacity for climate change adaptation** by building expertise, training, the knowledge base, monitoring and research to enable and support adaptation actions.
- **Raise awareness on climate change adaptation** by enhancing education and public awareness about climate change adaptation issues and the need for adaptation actions to be implemented in Bulgaria to build public acceptance and participation of adaptation-related policies and actions.
- **Build climate change resilience** by strengthening infrastructure and asset management and the protection of natural capital and covers water system infrastructure, energy supply infrastructure, and protecting and enhancing ecosystem services including those provided by forest resources.

The specific objectives for the agricultural sector comprised:

- Sustainable management of the agricultural practices for adaptation to climate change.
- Promote the adaptive capacity and awareness in agricultural sector.
- Promote research and innovation for climate change adaptation,
- Strengthen the policy and legal framework for adaptation in the agricultural sector.

The Strategy also proposed specific adaptation options for each sector by grouping them into vertical that address specific subsectors and horizontal covering the whole sector. It was further noted that the horizontal options could support the vertical options by enabling specific subsector actions.

The Strategy highlighted that the climate adaptation actions in the agriculture sector were needed both at the national and at the farm levels, with the engagement of the regional/local administrations and communities. The vertical options for the agriculture sector related to the first specific objectives, while the horizontal options related to specific objectives 2 to 4 (Table 5-1).

Table 5-1 Summary of the agriculture adaptation options (Source: Bulgarian Climate Change Adaptation Strategy and Action Plan, 2019)

Strategic objective	**Type of option**	**Examples**
Vertical options		
Sustainable management of the agricultural practices for adaptation to climate change	Agricultural productivity (Crops)	Adjust timing of farm operations; grow thermophilic crops; and develop suitable irrigation systems.
	Livestock production	Develop systems and mechanisms for storing water on farms; diversify livestock farming; and save existing pastures for grazing.
	Natural resource management (soil, water, fisheries)	Increase the use of perennial crops; improve water management practices; and maintain and improve existing aquaculture habitats.
Horizontal options		
Promote the adaptive capacity and awareness in	Building adaptive capacity	Develop climate change training; and develop knowledge dissemination actions.

agricultural sector	Improving awareness	Engage in wider dissemination of CCA knowledge to reach local farmers; and establish a formal platform for aquaculture.
Promote research and innovation for climate change adaptation	Research, technology development, and innovation	Develop research on new crop varieties; and develop farm-level resource management innovations.
Strengthen the policy and legal framework for adaptation in the agricultural sector	Risk management	Develop insurance and risk management programs
	Legal framework	Update and amend the legislation affecting fisheries and aquaculture

The Climate Change Adaptation Action Plan, 2019, prioritised the following options in the agriculture sector:

1. ***Horizontal adaptation options***

- Develop climate change training
- Develop knowledge dissemination actions
- Develop insurance and risk management programs
- Develop water management innovations
- Improve the climate change adaptation legal framework.

2. ***Vertical adaptation options***

- Improve water management practices
- Adjust the timing of farm operations

- Improve the soil structure maintenance, increase the soil organic matter reserves and improve the soil cultivation technologies
- Eliminate secondary salinization conditions and the anthropogenic soil acidification
- Maintain and improve existing aquaculture habitats.

5.2 Current institutions and mandates for climate change adaptation in Bulgarian rural areas

In Bulgaria, the ultimate responsibility for climate policy is with the Parliament, as stipulated in the Climate Change Mitigation Law. The Council of Ministers has the overall responsibility of any policy implementation. The climate policy is within the competences of the Ministry of Environment and Water (MoEW). The Bulgarian Climate Coalition[2] advocated for over a decade the need for recognising the high priority of climate policy and action. The first indication of the high level of political importance of climate change was given at the end of 2021, when a deputy prime minister on climate was appointed. However, the government was short-lived (13 December 2021 – 22 June 2022) and the next government did not renew either the priority or the position. Thus, climate remained one among equal policy topics in MoEW; the ministry not even (re)named as ministry of environment (water) and climate.

MoEW established a Climate Policy Directorate with a broad climate mitigation and adaptation policy mandate. The responsibilities comprised developing legal acts, coordinating the development and implementation of the national climate policy as well as coordinating the work of other ministries and institutions in relation to the national climate policy (Art.38, RCM 208/2023). However, it is the smallest specialised unit in the MoEW with only 11 staff members. In comparison, the Air Quality Directorate has 13 staff, the Water Management and Waste Management Directorates have respectively

[2] https://climatebg.org/en/documents/stanovishta/

24 and 23 staff, and the Nature Conservation Directorate – 32. At the same time, none of the subordinate MoEW institutions – the Regional Inspectorates, the River-Basin Management Directorates or the Executive Environmental Agency received an official climate adaptation mandate (Table 5-2).

Table 5-2 Climate mandates as regulated in the legal acts on the institutions' functioning (Source: Kazakova-Mateva, 2023. Institutions and mandates for climate change adaptation in Bulgarian rural areas. UNWE Conference report.)

Institution	Climate	Mitigation	Adaptation	Directorate	Legal act
Environment institutions					
Ministry of Environment and Water	x	x	x	Climate Change Policy	RCM 208/2017, 2023*
Executive Environmental Agency	x	x	.	Environment Monitoring, Permits	RCM 331/17.10.2022
Regional Inspectorates Environment and Water	.	.	.	.	MoEW, SG 54/2020
River-basin Directorates	.	.	.	.	MoEW, SG 54/2020
Agriculture Institutions					
Ministry of Agriculture and Food	x	.	.	Rural Development	RCM 260/2019
State Fund Agriculture	.	.	.	.	RCM 151/2012, 2020*
District Directorates on Agriculture	x	.	.	Agriculture Development	MoA, SG 41/2022
National Agriculture Advisory Service	.	.	.	.	MoA, SG 25/2022
Exec Agency Fisheries & Aquaculture	.	.	.	.	RCM 95/2010, 2020*
Food Risk Assessment Center	.	.	.	.	RCM 231/2016, 2020*
Bulgarian Agency on Food Safety	.	.	.	.	RCM 35/2011, 2020*
Executive Agency for Combating Hail	.	.	.	.	RCM 85/2000, 2021*
Agriculture Academy	.	.	.	.	RCM 151/2018, 2022*
Executive Forestry Agency	x	x	.	Forest Management	RCM 173/2011, 2022*

Notes: Resolution of the Council of Ministers (RCM)/ Order of respective minister in State Gazette (SG); * year of latest change

The Climate Change Mitigation Law and the Third National Plan on Climate Change Mitigation 2013-2020 (3rdNPCCM) planned for the setting up of dedicated climate units in the related ministries, including in the Ministry of Agriculture (MoA). In 2022, the final implementation report of the 3rdNPCCM disclosed that the MoA declined the setting up of such unit. The justification provided was the "*cross cutting character of climate change affecting the work of multiple units in the MoA system*" (p.32). The MoA stated that the "*existing structure was sufficient to ensure a good coordination of issues requiring a complex approach and complementarity*". The functional structure regulations of the agriculture institutions revealed that there was only one unit in the MoA with official climate related functions. This was the Rural Development Directorate, which was responsible for the programming of the Common Agriculture Policy (CAP) support. One of its over 15 other functions was to "*program appropriate measures and schemes <u>to combat climate change</u>, to protect soils, biodiversity and water resources, through which to ensure the fulfilment of commitments related to the environment and climate, arising from the applicable European legislation for the European Structural and Investment Funds*" (Art.38(1) p.11), RCM 260/2019). Again, climate change was one of four environmental issues to be addressed.

The other MoA institution with climate related responsibilities was the Executive Forestry Agency. Its Forest Management Directorate had two functions related to climate change mitigation – to participate in intra-institutional meetings and working groups and to develop and implement projects on climate change mitigation in forests. None of the functions mentioned explicitly climate adaptation responsibilities.

The 2019 Climate Change and Adaptation Strategy assessed the institutional capacity on climate change adaption as needing improvement "*at all levels and in all sectors*". The proposed focus was on "*building expertise, training of the administration* *and stakeholders, the knowledge base, monitoring and research to enable and support adaptation actions*" (CCAS, 2019).

The public bodies' decision-making on climate issues was regulated in the Climate Change Mitigation Law. It stipulated that a National Expert Council on Climate Change supported the Minister of Environment and Water. Thus, the Council was established as a consultative body. Its members comprised representatives of nine other ministries, the Executive Environmental Agency, the Bulgarian Academy of Science, the Association of Municipalities as well as other non-governmental bodies. The Ministry of Agriculture and Food was one of the members. The operation of the Consultative Council was regulated by an Order of the Minister of Environment and Water. The order stipulated that its operating principles were transparency, publicity and equality among its members.

5.3 Recommendation

5.3.1 Adaptation options for agriculture sector

Based on the Climate Adaptation Strategy and Action plan, the adaptation options can be divided into: Vertical; Horizontal; Cross-cutting.

(a) Vertical adaptation options

Based on the impact of climate change on the agricultural sector, adaptation options can be grouped into the following:

1) Adaptation options for agricultural productivity

Irrigation infrastructure and irrigation system implementation can help achieve higher yields and productivity. Another option is better management of woodland, hedgerows, and trees on agricultural land that will benefit the livestock and crop sector. Better management of farm operations and better pest and disease control are also adaptation options. In addition, developing new varieties better adapted to new conditions and climate change effects can be pointed out as an option.

2) Adaptation options for livestock

The adaptation options in this field include developing systems and storage for water and efficient and optimal water use. In addition, new alternative energy sources can be used on the farm level. Improving cooling and heating systems is an important part that could help maintain animal health and welfare. In this direction, a significant aspect is the development of new livestock breeds, changes in diet patterns of animals and better management of grassland.

3) Adaptation options for natural resources

Regarding the soil, a critical adaption option can be using perennial crops that are more resistant to climate change as extreme weather conditions. Another option is maintaining soil structure and increasing soil infiltration capacity and organic matter reserves. Soil management should be improved by increasing water retention to conserve soil moisture. Better use of crop residues as raw material is an important part of these options and is at the centre of the emerging bioeconomy.

Regarding water resources, better irrigation management and practices are essential. The secondary salinization conditions have to be eliminated.

(b) Horizontal adaptation options

1) Building adaptive capacity

In this direction, important options are staff training in different institutions and organizations among the main stakeholders. In addition, dissemination actions such as conferences and seminars can be organized. Financial support such as grants, subsidies or other instruments could boost the implementation of the new practices.

Crucial for adapting to climate change is developing and improving a monitoring and evaluation system.

2) Better awareness

Options in this field include different online portals or platforms with specific information that will engage society. In addition, dissemination among farmers is also important. Opportunities for local community engagement are newsletters, workshops, and brochures. Introduction climate change challenges in education in schools and universities curricula can be outlined as an option. Developing enhanced ecosystem observation systems is also a step-in adaptation to climate change.

3) Strengthening research, technology development, and innovation

In this field, a wide range of options includes different stakeholders. The research of new crop varieties and livestock breeds is an important step. Further and broader studies on the impact of climate change on different sectors and interaction between sectors are the options for a better understanding of the processes.

On the farm level, better management of resources and implementation of new technologies and innovations is essential. These innovations include irrigation systems, water use and new renewable energy resources.

Better climate information systems are recommended and can help combat climate change.

4) Risk management and legal framework

In this direction, important steps are developing insurance and risk management programs. In addition, harmonization and adapted legal framework concerning the Green Pact and other EU actions is vital part of the adaptation.

(c) Cross-cutting

Coordination and interaction between different institutions, organizations and other stakeholders is crucial. Climate change is linked to the quality of natural resources, urban and rural development, food security and human health. Therefore, the adaptation strategies include rural and urban development and should be considered together. Adapting to climate change requires the adoption of an integrated approach which includes social, economic and environmental aspects.

Promoting synergies between adaptation and mitigation in agriculture can help develop and implement adaptation strategies. Risk assessment and monitoring frameworks that include different actors are also essential. Research, knowledge transfer and dissemination of the best practices are important for adaptation to climate change.

5.3.2 Adaptation options for forestry sector

In Bulgaria, forests provide important inputs to the economy through timber and non-timber forest products, including ecosystem services. The Bulgarian government recognizes the importance of the forest sector in its national communication and national forest sector development strategy. Facing the pressure brought by temperature and hydrological changes, adaptation work can be carried out, which can improve forest health and protect biodiversity in the short term. Increasing research and promotion to promote sustainable forest utilization is crucial for effective forest management. In areas where forests are under pressure or prone to flooding, investing in reforestation can not only improve forest health but also alleviate flooding. Supporting biodiversity and genetic diversity in forests through accommodation, conservation, and restoration practices is also an important approach that can be taken. The current forest management methods must be changed to ensure the long-term availability of resources.

5.3.2 Adaptation options for water & energy sector

For water sector, the sustainable utilization of surface water, groundwater, and river systems is an effective effort to limit the impact of human behavior such as runoff and wastewater management pollution, and is also a requirement for the long-term availability of water resources. Bulgaria's water sector can adopt adaptive options by strengthening adaptive water management technologies, including scenario planning, learning based methods, and flexible and low regret solutions in the face of expected climate risk trends, to support more adaptive governance. Considering poverty alleviation and equity, financial tools can be developed to achieve more sustainable water resource management. It can support engineering plans to develop and integrate ecologically efficient climate adaptation and risk mitigation water infrastructure. Water can be transferred to water scarce areas in the country. Bulgaria's vertical adaptation strategy needs to include national level policies to support adaptive governance of water resources through legislation and cooperation in shared resources such as river basins.

For energy sector, the adaptation choices of the energy sector need to include the transition from fossil fuels to renewable energy in highly uncertain situations, especially in terms of hydrological changes. Adaptation options should focus on energy security and energy investment strategies, including components of climate change, including preparing for future energy needs and reducing risks for critical infrastructure in vulnerable areas. The adaptation measures for the Bulgarian energy sector include:

- Convert monitoring, forecasting, and weather data for the energy sector
- Mainstream climate change considerations into energy sector policies and plans
- Integrating climate adaptability into the design and engineering of new power plants, as well as the operation and emergency plans of existing power plants and coal mines
- Integrating climate adaptability into the design and engineering of new T&D infrastructure, as well as the operation and emergency planning of existing T&D infrastructure
- Diversified supply, including regional energy trade, regional heating/cooling, household gasification, and small-scale renewable energy, to enhance the overall resilience of the energy system
- Improve the energy efficiency of public and private sector buildings to ensure the maintenance of existing supply-demand balance
- Establish institutional capabilities and knowledge networks
- Developing financial mechanisms to establish resilience

Developing knowledge tools to provide information for integrated energy strategies incorporating climate change will require knowledge products such as maps and regional forecasting estimates. It is worth noting that financial mechanisms need to be established for large-scale investments required for energy production and distribution. It is necessary to incorporate resilience planning into the current energy plan to ensure long-term energy resilience.

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