The studies contained in this unformatted document have been copyedited and will be included in the forthcoming REC publication of the same name.

The Impacts of Climate Change on Food Production in the Western Balkan Region

Edited by Zsuzsanna Ivanyi
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Foreword

According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), published in 2007, South Eastern Europe (SEE) is one of the most vulnerable areas in Europe to the consequences and impacts of climate change. This has been confirmed by recent calculations in regional and national studies using regional climate models for the SEE region (the area referred to in this publication as the Western Balkans). The impacts of climate change include the increased magnitude of floods and droughts and greater resulting damage, as well as reduction in crop yields. The decreased availability of water may also affect hydro-power production in the energy sector, and higher numbers of people are exposed to vector- and water-borne diseases. Adaptation could essentially reduce these effects.

Recognising the need to combat the significant impacts of climate change, some Western Balkan countries have launched activities and initiated meetings to enhance cooperation. At the First Thematic Climate Change Conference, held in Sarajevo on November 14, 2008, a joint statement was issued by the ministers of environment of Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro and Serbia (the participating countries), stating the establishment of a common political platform of the countries. The ministers also expressed their support for the South East European Climate Change Framework Action Plan for Adaptation (SEE/CCFAP-A), as presented at the 2008 Sarajevo meeting. The adopted SEE/CCFAP-A, which runs from 2009 to 2015, provides a framework to tackle adaptation-related issues. The implementation of the action plan is hampered by a variety of factors, including lack of financial resources, willingness and interest on the part of stakeholders to initiate activities.

The countries of the Western Balkans face severe economic difficulties: the standard of living is lower than in the EU; unemployment rates are high; and economic growth is relatively modest. The acceleration of economic reforms is a huge challenge, but at the same time it can be seen as an opportune moment to integrate climate change aspects into the newly drafted national development plans.

Agriculture is an important sector of the economy in Western Balkan countries. Due to the region’s climate, agriculture—in particular the production of crops, fruits and vegetables—has traditionally been a crucial contributor to the national economies. Agriculture provides the income basis for a high proportion of the population and employment for many. At the same time, agriculture is the second highest contributor, after the energy sector, to national greenhouse gas (GHG) emissions in Western Balkan countries.

The papers in the present publication focus on the knowledge, experience and results acquired in the course of research analysing the impacts of climate change on crop yields in five countries. The reports from Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia and Serbia provide examples of efforts to identify risks related to climate change and the main effects on the production of important crops. At the same time, they highlight the gaps and barriers that central and local governments need to address. The authors of the studies provide recommendations
for decision makers as to the most urgent actions needed to pave the way to incorporating climate change aspects into agricultural development plans and shaping appropriate strategies and policies.

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The impact of climate change on food production/selected crop yields in Albania

Abdulla DIKU MSc.

This study has been prepared within the framework of the project “Impact of climate change on food production/selected crop yield in Albania”, implemented through a grant from the Regional Environmental Center for Central and Eastern Europe (REC). The assessment aims to identify current Albanian experience in dealing with climate variability and its impacts on food production and crop yields.

The following national authorities, correspondents and experts provided information for the study: Professor Dr. Tatjana Dishnica, scientific director at the Ministry of Agriculture, Food and Consumer Protection; Professor Dr. Pellumb Abeshi, general director of polices at the Ministry of Environment, Forest and Water Administration; Associate Professor Eglantina Demiraj, project coordinator for the GEF/UNDP project “Identification and implementation of adaptation response measures in the Drini–Mati River Deltas”; Professor Thimaq Lako, expert on forest and climate change from the National Association of Communal Forests and Pastures; Dr. Zamir Dedej, biodiversity and climate change expert, Institute of Nature Conservation in Albania; Dr. Genti Kromidha, expert on forests and climate change, Institute of Nature Conservation; and Dr. Hamdi Beshku, climate change expert and hydro-geologist.

Overview

Agriculture is the most climate sensitive of all economic sectors. In Albania, the impacts of climate change on the agricultural sector represent an urgent problem, since the majority of the rural population depends either directly or indirectly on agriculture. The rural poor will be disproportionately affected because of their greater dependence on agriculture, their relatively lower ability to adapt, and the high proportion of their income that is spent on food. The impacts of climate change could therefore undermine the progress that has been made in poverty reduction and could adversely affect food security and economic growth in vulnerable rural areas. Increased exposure to high temperatures, drought, and shifting seasonal patterns, increased incidence of diseases and pests and soil erosion are already beginning to damage agricultural productivity. At the same time, climate vulnerability has been exacerbated by sub-optimal policies, the deficient management of natural resources and associated infrastructure, and poor adaptive capacities.

Soil erosion is a huge problem: 60 percent of the territory is affected, while 30 percent of agricultural land has annual soil loss rates of around 20 to 70 tons/ha.

As the agricultural sector is the biggest consumer of fresh water, at 60 percent of the total, water resources are an important issue. Extreme events such as floods, droughts and fires have occurred in recent years, but no integrated assessment has been carried out to measure the costs from an economic, social and environmental perspective.

Climate change influences a range of biophysical factors, including plants and animals, water, biodiversity and nutrient cycles, as well as the ways in which these are managed through agricultural
practices and land use for food production. However, there is still little available capacity within the Ministry of Agriculture, Food and Consumer Protection and its agencies at regional and local levels to provide information and assist farmers in coping with climate change effects, risks and opportunities.

It is essential to mainstream and integrate climate change issues into policy and investment decisions, since changes in agricultural patterns and performance will affect food supply at local as well as global levels. In low-income countries that have limited financial capacity to trade and that are highly dependent on their own production to meet demand, it may not be possible to offset reductions in local supply without increasing reliance on food aid. At the same time, producer groups that are less able to deal with climate change, such as the rural poor in developing countries, risk having their safety and welfare compromised.

Main findings of the present study can be summarised as follows:

- Temperatures are rising and precipitation is becoming more variable in Albania as a result of climate change. These recent changes will persist and grow more severe over the coming decades.

- The direct impacts of changes in temperature and precipitation in the future will be mixed — climate change is forecast to improve yields of wheat and irrigated alfalfa; to reduce harvests of grapes and olives; and to have relatively modest effects on the other crops included in the study.

- Farmers in Albania have not adequately adapted to current changes in the climate. In light of this large “adaptation deficit”, many of the climate adaptation measures implemented will be able to improve resilience to more severe climate impacts in the future.

- Water resources are abundant in Albania, and according to some forecasts they will continue to be abundant through 2050 under a wide range of climate change scenarios. In many cases, however, additional investment will be needed in the irrigation and drainage infrastructure in order to take advantage of these water resources in the agricultural sector.

- The direct effects of climate change on the livestock sector, particularly beef cattle, chickens and sheep, could be substantial, reducing productivity by up to 25 percent by 2050. These effects would be felt gradually over time, however, and farmers have confirmed that they have not seen any immediate effects of climate change on livestock production.

- National-level adaptation is a high priority. Policy changes and institutional capacity improvements that could be undertaken immediately include expanding extension service capacity; improving the provision of short-term meteorology forecasts for farmers; and encouraging the consolidation of farmland into larger holdings to facilitate more substantial investments in on-farm technology.

- At the level of agro-ecological zones and farms, high-priority adaptation measures include improving drainage, rehabilitating secondary irrigation capacity, optimising fertiliser and water application, providing more climate resilient seed varieties and the know-how to cultivate them effectively for high yields, and encouraging the wider use of hail nets.

- Prior to this report, there has been no specific analysis or study of the effects of climate change on food security in the country. Climate change scenarios indicate that food security will depend on the ability of the country to implement adaptation measures in response to the changes.
1. Country profile: National economic and geographic conditions, latest GHG emissions data, and the role of agriculture/food production

The Republic of Albania is situated in South Eastern Europe in the south west of the Balkan Peninsula on the Adriatic and the Ionian Seas.
The main geographical regions are therefore coastal lowlands, the intermediate hill country, and the mountain ranges that rise to altitudes of around 2,000 m above sea level. The average altitude is 708 m above sea level, which is twice as high as the European average. The average amount of agricultural land per capita is the smallest in Europe, at 0.2 ha.

1.1 Geographic and climatic conditions

With its Adriatic and Ionian coasts, intermediate hills and highlands backing onto the elevated Balkan landmass, Albania has a high number of climatic regions for so small an area. The coastal lowlands have typically Mediterranean weather patterns, while the highlands have a Mediterranean continental climate. In both the lowlands and the interior, there is a marked difference in weather patterns from north to south.

Temperatures
Albania has a typically Mediterranean climate characterised by mild winters with abundant precipitation and hot, dry summers. The annual mean air temperature varies widely over the territory from 7°C over the highest zones up to 15°C in the coastal zone. In the south west, temperatures reach up to 16°C. In the lowland, an almost stable distribution of annual mean temperature (between 12 and 14°C) can be observed. The lowest recorded temperature was –25.8°C and the highest 43.9°C.

Precipitation
Total mean annual precipitation over Albania is about 1,485 mm per year. The spatial distribution varies quite widely. The southeast part of the country receives smaller amounts of precipitation (an annual value of up to 600 mm), followed by the Myzeqeja field, which receives about 1,000 mm per year. The highest precipitation total is recorded in the Albanian Alps, where values reach as much as 2,800 to 3,000 mm per year. Another area with abundant rainfall is the mountainous southwest zone, where total precipitation is up to 2,200 mm. Precipitation levels follow a clear annual pattern, with the maximum in winter and the minimum in summer. The biggest share of precipitation (about 70 percent) is recorded during the cold months (October to March). The richest month in terms of precipitation over the territory as a whole is November, while the poorest months are July to August. Snow is characteristic in inland mountainous regions, that is, the Albanian Alps and the central and southern mountainous regions. It is rare in the West Plain lowlands, and especially on the southwestern stretch of the Albanian coast. Precipitation levels and patterns represent a key factor in national electricity production, since the country produces the majority of its electricity from
hydropower plants. It is also very important for agriculture, which is still the country’s most important economic activity.

1.2 Economic data

Albania remains a poor country by Western European standards. Its GDP per capita (expressed in purchasing power standards, or PPS) stood at 26 percent of the EU average in 2010.

Agriculture is the most significant sector of the economy, employing some 44 percent of the labour force and generating about 18.5 percent of the country’s GDP (see figure 2). Albania produces significant amounts of wheat, corn, tobacco, figs (13th largest producer in the world in 2005) and olives.

![Figure 2. Structure of GDP by economic activities](image_url)

Rural families continue to dominate the national economy: more than 50 percent of the population lives in rural areas, and agriculture is their main possibility for employment. In real terms, the average increase in the rate of agricultural production during the last five years is estimated at about 3 percent per year.

One disadvantage in the agricultural sector is the small size of the farms (at 0.2 ha/inhabitant) and the fragmentation of farmland, both of which represent a barrier to production and marketing.

Growth in the agricultural sector is below the mean national rate and far from reaching its potential. This is the result of the specific problems that the sector is facing, the most obvious of which are related to migration from rural areas; land ownership and limited farm size; product marketing; irrigation and drainage systems; the low level of technological development; weak organisation among farmers; and the low level of development in agro-processing.

Approximately 3,250 kinds of plants, or 29 percent of European flora and 47 percent of Balkan flora species, are found in Albania.

The figure below indicates the contribution of various economic sectors in terms of employment.
1.3 The Agriculture and Food Sector Strategy

The Agriculture and Food Sector Strategy (AFSS) was prepared in 2007 in the broad planning and monitoring framework of the Integrated Planning System (IPS). The present agricultural policy contains the following strategic priorities:

- Increase financial support to farms, agricultural and agro-industrial businesses with special emphasis on fruit trees, vineyards, vegetables and animal farming, as well as on the industrial processing of fruit, grapes, vegetables, milk and meat, according to the natural advantages of the different areas of the country.
- Improve the management, irrigation and drainage of land.
- Improve the marketing of agricultural and agro-processing products in order to increase the competitiveness of domestic agriculture.
- Improve the level and quality of technologies, information and knowledge applied by farmers and agro-processing businesses through support to Agricultural Information Centres and Agricultural Technology Transfer Centres.
- Increase the quality and safety of agricultural and agro-processing products for the period 2007 to 2013.

Strategic sectors over the period 2007 to 2013 are:

- fruit, olive and grape production;
- vegetable production;
- livestock production;
- the industrial processing of fruits and vegetables;
- the industrial processing of grapes; and
- the industrial processing of milk and meat.

One significant shortcoming in these strategies is the absence of any climate change mitigation measures, which various players in the country are trying to address.
1.4 Agricultural land

The share of agricultural land represents only 24 percent (about 697,000 ha) of the total area of the country. About 43 percent (about 304,000 ha) of the total agricultural land is in the lowland area, where the productivity potential is relatively high.

Out of the total of 697,000 ha of agricultural land in Albania, approximately:
- 563,000 ha have been privatised; and
- 134,000 ha remain in state ownership.

![Figure 4. Structure of land (percentages)](image)

At present, the total area of land under cultivation is about 80 percent of the total land owned by private farmers, and land-use policies are developed accordingly. The land market in Albania is still in its initial stages and a package of integrated measures is needed for its development and consolidation.

Albanian agriculture is dominated by a large number of small farms. In 2009 there were approximately 353,486 household farms in the country, the average size of which is very small at 1.14 ha, according to official statistics, or 0.8 ha according to the 2007 World Bank Household Budget Survey (HBS). This is distributed across an average of 4.1 parcels, with an average parcel size of 0.27 ha.

This is compared to an average of 5 ha in Central and Eastern European countries and 27 ha for Western Europe. This is an important barrier to the improvement of agricultural productivity and to the sustainable development of the agricultural sector.

The percentage of household farms of various sizes is shown in figure 8.

![Figure 5. Farm size (ha)](image)
Although farms are extremely small and fragmented, there has nevertheless been an increase in output as new farm owners have worked intensively to improve their productivity.

### 1.5 Agricultural mechanisation, inputs and irrigation

Only 74 percent of household farms use machines for ploughing; around 23 percent use animals for ploughing, and 59 percent use a combination of machines and manual labour. In Albania, there is one tractor per 70 ha.

At national level, about 93 percent of all farmers use chemical fertilisers, which constitute about 23 percent of total farm expenditure.

Only around 40 to 45 percent of farmers use purchased feed for livestock.

The total area that can be irrigated at present is 195,000 ha, out of a total area of 335,000 ha that are suitable for irrigation.

Ongoing investments are being made in the rehabilitation of the irrigation infrastructure, which constitutes a large percentage of public expenditure in the agricultural sector.

The total area that the drainage system has been designed to cover is 280,000 ha, although in reality the system operates on only 200,000 ha. The drainage system is designed to drain 205,000 ha using by gravity; and 75,000 ha through pumps.

### 1.6 Crop production

Agricultural production and income have been steadily increasing. The proportions of crop and fruit production are 44 percent and 11 percent respectively, while livestock production accounts for about 46 percent of total agricultural production. The highest growth rates can be seen in fruit and livestock production.

The main agricultural products are grains (especially wheat), vegetables, potatoes and beans (37 percent). Grains are cultivated for consumption by the growers, with very small quantities supplied for the market. Vegetables, potatoes and fruits are more oriented to market supply and represent an important source of income for family farms. Forage crops (maize and alfalfa) are cultivated on about 49 percent of total farm surface area.

Vegetable production in greenhouses has notably increased, largely due to market demand and the high level of income per unit of surface area.

![Figure 6. Structure of crops](image)

**Figure 6. Structure of crops**
1.7 Agro-ecological zones

Albania is divided into four agro-ecological zones: (i) coastal lowlands; (ii) intermediate zone; (iii) north central mountains; and (iv) southern highlands (see figure 11). In the framework of the study “Reducing the Vulnerability of Albania’s Agricultural Systems to Climate Change” (IEc 2010), an analysis is being developed for each of these zones with respect to climate change impacts and adaptation measures.

![Figure 7. Agro-ecological zones in Albania](image)

1.8 GHG emissions

Total GHG emissions in Albania in 2000 were 7,619.9 gigagrams (Gg). The main contributors are the energy sector (44 percent), agriculture (27.12 percent), and land-use change and forestry (21.6 percent). Per capita GHG emissions in Albania were 2.47 tons of CO₂ equivalent, which is four to five times lower than the average in industrialised countries. This is due to generally low energy consumption: more than 90 percent of electricity is produced by hydropower plants and most energy is consumed as electricity.

![Figure 8. GHG emissions from all economic sectors (Gg CO₂ eq)](image)
Most of the GHG emissions from agriculture are in the form of CH\(_4\) and N\(_2\)O. Sources of CH\(_4\) emissions are mainly enteric fermentation and manure management. Cattle are the main contributor of CH\(_4\) emissions from enteric fermentation, followed by sheep. Emissions of N\(_2\)O from crops are mainly produced from the application of nitric fertilisers. Emissions of CH\(_4\) and N\(_2\)O from crop management are insignificant and are the result of burning agricultural residues.

2. Vulnerability of Albanian agriculture to climate change

The most comprehensive assessment of climate parameters in Albania is provided in the Second National Communication (SNC2), submitted under the United Nations Framework Convention on Climate Change. Other studies, such as *Adapting to Climate Change in Europe and Central Asia* (World Bank, 2009), provide a general view of the challenges Albania will face in the context of climate change. The Climate Change Index developed by Baettig et al. (2007) combines three sub-indices referring to a country’s exposure, sensitivity and adaptive capacity. The assessment of exposure is based on an index measuring the strength of future climate change relative to present-day natural variability. The index is available on a country basis and includes both annual and seasonal temperature and precipitation indicators. It combines the number of additional hot, dry and wet years; hot, dry and wet summers; and hot, dry and wet winters projected over the 2070 to 2100 period relative to the 1961 to 1990 period.

The second sub-index, a country’s sensitivity to climate change, is based on indicators likely to increase the impact of climate events. This includes physical indicators, such as available renewable water resources per capita and the extent of air pollution (since particulate matter in the air exacerbates the impact of heat waves); economic indicators of the importance of agriculture to the economy (share of employment and value of assets); and the proportion of electricity derived from hydroelectric plants.

The third sub-index, adaptation capacity, is estimated by combining social (income inequality), economic (GDP per capita) and institutional measures. The index developed by Baettig et al. uses principal component analysis (PCA) to calculate the sensitivity and adaptive capacity indicators, as well as to combine all three indices into the overall vulnerability index. PCA is a statistical technique that picks the weight given to each component of an index formula in order to best explain the variance in the data. The exposure sub-index developed by Baettig et al. (2007) uses a simple linear formula to combine the underlying variables and is designed to indicate the impact of future climate change relative to today’s natural variability. It suggests that the European and Central Asian countries most exposed to increased climate extremes are Russia, Albania, Turkey and Armenia, and, to a lesser extent, the former Yugoslav Republic of Macedonia and Tajikistan.
Figure 9. Exposure of European and Central Asian countries to increased climate extremes by the end of the 21st century
Source: Baettig et al. (2007). The index combines the number of additional hot, dry and wet years; hot, dry and wet summers; and hot, dry and wet winters projected over the 2070 to 2100 period relative to the 1961 to 1990 period. Countries already experiencing substantial variability and extremes are less likely to rank highly on this index (e.g., India and the Czech Republic have around the same score).

2.1 Temperature and precipitation
Likely changes in temperature and precipitation in Albania are presented in Table 2. Temperatures are expected to increase and precipitation is expected to decrease, giving rise to milder winters, warmer springs, hotter and drier summers and drier autumns.

Table 1. Climate change scenarios for Albania

<table>
<thead>
<tr>
<th>Season</th>
<th>Time horizon (years)</th>
<th>2025</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature (°C)</td>
<td>0.8 to 1.1</td>
<td>1.7 to 2.3</td>
<td>2.9 to 5.3</td>
</tr>
<tr>
<td></td>
<td>Precipitation (%)</td>
<td>-3.4 to -2.6</td>
<td>-6.9 to -5.3</td>
<td>-16.2 to -8.8</td>
</tr>
<tr>
<td>Winter</td>
<td>Temperature (°C)</td>
<td>0.7 to 0.9</td>
<td>1.5 to 1.9</td>
<td>2.4 to 4.5</td>
</tr>
<tr>
<td></td>
<td>Precipitation (%)</td>
<td>-1.8 to -1.3</td>
<td>-3.6 to -2.8</td>
<td>-8.4 to -4.6</td>
</tr>
<tr>
<td>Spring</td>
<td>Temperature (°C)</td>
<td>0.7 to 0.9</td>
<td>1.4 to 1.8</td>
<td>2.3 to 4.2</td>
</tr>
<tr>
<td></td>
<td>Precipitation (%)</td>
<td>-1.2 to -0.9</td>
<td>-2.5 to -1.9</td>
<td>-5.8 to -3.2</td>
</tr>
<tr>
<td>Summer</td>
<td>Temperature (°C)</td>
<td>1.2 to 1.5</td>
<td>2.4 to 3.1</td>
<td>4.0 to 7.3</td>
</tr>
<tr>
<td></td>
<td>Precipitation (%)</td>
<td>-11.5 to -8.7</td>
<td>-23.2 to -17.8</td>
<td>-54.1 to -29.5</td>
</tr>
<tr>
<td>Autumn</td>
<td>Temperature (°C)</td>
<td>0.8 to 1.1</td>
<td>1.7 to 2.2</td>
<td>2.9 to 5.2</td>
</tr>
<tr>
<td></td>
<td>Precipitation (%)</td>
<td>-3.0 to -2.3</td>
<td>-6.1 to -4.7</td>
<td>-14.2 to -7.7</td>
</tr>
</tbody>
</table>

Source: Climate change scenarios for Albania. Albanian Second National Communication, 2009

Likely changes in other climatic parameters are described below:
- Droughts are expected during the summers due to higher temperatures (with a likely increase of up to 5.6°C) and potential evaporation that is not balanced by precipitation (which is likely to decrease by 41 percent).
- Increasing temperatures will raise the probability of extreme events and higher intra-annual variability of minimum temperatures. There is likely to be a higher increase of daily minimum temperatures than maximum temperatures. More frequent and severe droughts are likely, with a greater risk of fires.
- There is likely to be a decrease in the number of frost days (with temperatures of ≤-5°C) in high altitudes of four to five days, nine days and 15 days by 2025, 2050 and 2100 respectively.
- Owing to higher average temperatures in winter, more precipitation is likely to fall in the form of rain rather than snow, which will increase both soil moisture and run-off. The increase in the total precipitation rate may lead to greater risks of soil erosion, depending on the intensity of the rain episodes.
• The increase in summer temperatures is likely to result in an increase in the frequency and intensity of extreme weather events (heat waves). The number of days with a temperature of $\geq 35^\circ\text{C}$ is likely to rise by one to two days by 2025, and by three to four days by 2050 compared to the 1951 to 2000 average. By 2100, the expected increase is between five and six days in mountainous areas and up to eight days in lowland areas.

• The expected changes in surface air temperature and humidity will raise the heat index (i.e. the combined effect of temperature and moisture). More hot days and heat waves are very likely over nearly all of the whole country. The increase will be biggest in the lowland areas of Albania, where a reduction in soil moisture is likely.

• Although total precipitation is expected to decrease, an increase in episodes of intensive rain is likely. The number of days with heavy precipitation (24 hours maximum) compared to the 1951 to 2000 average is likely to increase by one to two days by 2025, by two to three days by 2050, and by three to five days by 2100.

2.2 Expected changes in sea level

Scenarios developed to assess the impacts of a rise in sea level project an increase in losses of wetland area (of around 1 km$^2$ by 2100). They also project an increase in the coastal floodplain area and population. Because of their geographical location and topography, the forecast changes in sea level will have a great impact on Albanian agriculture in coastal areas. In the winter of 2010, for example, a rise in sea level associated with storm surges and heavy rain caused flooding on more than 10,000 ha of agricultural land, resulting in significant economic loss. Farmers are concerned about corn growth and development and about the effect of short periods of flooding on yields. The amount of damage caused to corn crops by flooding is determined by the stage of growth at which the flooding occurs; the frequency and duration of the flooding; and the air and soil temperatures during the flooding.

Flooding reduces the exchange of air (oxygen) between soil and atmosphere, eventually leading to decreased total root volume, poorer transportation of water and nutrients through the roots to the shoots, and the formation of sulphides and butyric acid by micro-organisms, which are toxic to plants.

2.3 Effects of climate change on natural resources

2.3.1 Water resources

Patterns of change in terms of water resources broadly correspond to changes in annual precipitation — that is, an increase in areas at high altitudes and a decrease in areas at mid-altitude. However, the general increase in evaporation means that a reduction in run-off is probable (figure 14). The following changes are likely to arise as a result of climate change impacts in the water sector:

• Higher temperatures will shift the snowline upwards: seasonal snowfall patterns are likely to change, with the snow season beginning later and ending earlier. Spring run-off is therefore expected to decrease significantly, with a maximum reduction of 30 percent and 66 percent by 2050 and 2100 respectively. This is something that must be taken into account by the hydropower industry.
• Riverine flood risk will generally increase, with the period of greatest risk shifting from spring to winter.
• A rise in sea level can lead to several direct impacts, including the inundation and displacement of wetlands and lowlands, coastal erosion, increased storm flooding and damage, increased salinity in estuaries and coastal aquifers, and rising coastal water tables.
• Groundwater supply will be affected by the decreased percolation of water due to a decrease in the amount of precipitation and stream flow, and loss of soil moisture due to increased evapotranspiration.
• A reduction in groundwater supply, in combination with its increased salinity, can lead to a shortage of drinking water of appropriate quality.

2.3.2 Agriculture

The following impacts are likely in relation to annual crops:

• The total growing season may be reduced for some crops due to the rise in temperature. Cereals would be harvested earlier.
• A lack of cold days during December and January could reduce the effects of vernalisation and consequently lengthen the first part of the growing season for winter wheat. Air temperature in April could slow down biomass growth and reduce wheat yield.
• The expected increase in temperature will cause faster rates of development and shorten the length of the growing period for some crops, consequently shortening the length of the grain-filling period.
• Higher temperatures during the growth season will increase the development rate of all winter crops, which will therefore face extreme events (cold spells) at a later stage when they are more sensitive.
• Higher summer temperatures (up to 5.5°C higher by 2100) should not be very detrimental to summer crops (with the exception of spring cereals, if subjected to elevated temperatures during the grain-filling period), since they are more resilient than winter crops. Drought could be a major concern in the future.
• Higher temperatures will probably be beneficial to grasslands, at least early in the season, through increased early biomass production. Higher temperatures during the summer may decrease the growth capabilities of grass.
• Weeds are expected to benefit from higher CO₂ concentrations. The results of crop-weed competition will depend on their respective reactions to climate and atmospheric fertilisation.
• In general, higher temperatures may shorten the reproductive cycle of many pests, thus the risk of crop damage from pests and diseases may increase as a result of climate change.

| Table 2. High temperature and soil moisture effects on major field crops |
| --- | --- |
| Crop | Effects |
| Maize | Temperatures above 36°C cause pollen to lose viability. Maize is extremely sensitive to soil moisture deficits. Four days of visible wilting in the period before the tasseling stage reduces yield by 10 to 25 percent; between the week before tasseling and the milk stage of development it reduces yield by more than 50 percent; and in the soft dough stage it decreases yield by 40 percent. Aflatoxin concentration rises when the crop has a water deficit. Very intolerant to flooding except after the silking stage; the effects of flooding depend on temperature. Before the sixth leaf stage the crop does not survive more than four days of flooding if the temperature is lower than 25°C; and less than 24 hours if the temperature is lower than 20°C. |
Soybean

- Temperature is above 25ºC.
- When the crop is less than 15 cm high, 24 hours of flooding reduces yield by 18 percent at any temperature.
- Continuous soil saturation causes long-term problems related to rot development and increased damage by diseases (e.g. crazy top and common smut).
- Soil temperature higher than 35ºC at planting causes seedling death. Very sensitive to temperatures above 35ºC during the first three weeks after bloom. Great ability to recover from temperature stress at other times.
- Sensitive to soil moisture deficits and drought at planting and from bloom to pod-fill. Very sensitive to soil moisture deficits during pod-filling and seed enlargement.
- Relatively tolerant to excess soil humidity, but saturated soils increase the risk of seedling diseases especially in temperatures above 32ºC.
- Temperatures above 30ºC for more than eight hours can reverse vernalisation.

Wheat

- Flowering, pollination and grain-filling stages are sensitive to water stress.
- Excess soil moisture causes waterlogging and increases the risk of fungal infestations.

2.3.3 Forestry

In general, evergreen species and oak forests are expected to expand, while the area of beech forests, which are more important in terms of wood production, is likely to decrease. Common spruce forest (Picetum) is expected to disappear by 2025, while the alpine pasture on top of high mountains would be reduced tenfold (from over 20 percent of forest area to 2 percent).

3. Vulnerable areas in the country based on scenarios

A more detailed analysis of the effects of climate change on agriculture were carried out by the IIEc and published in 2010 in the study “Mainstreaming climate change adaptation to Albanian agricultural policies”. According to this study, changes in precipitation are far more uncertain than changes in temperature, as shown in figure 15. The medium-impact forecast indicates a decrease in precipitation nationally of about 50 mm per year, mostly occurring in the lowlands agro-ecological zone. The range of outcomes across the alternative low- and high-impact scenarios, however, is plus or minus 100 percent. Uncertainty at regional level is even higher, and the decrease in annual precipitation in the lowlands and intermediate agro-ecological zones, including the areas around Lushnje, Vlores, Fushe-Kruje and Shkoder, could be as large as 150 mm per year. Most models show only modest reductions in annual precipitation in the mountainous areas of Albania, particularly around Korce.

However, national averages are less important in terms of agricultural production than the seasonal distribution of temperature and precipitation. Temperature increases are higher in July and August relative to current conditions: summer temperature rise can be as much as 4 to 5ºC in the northern mountains of Albania, when temperatures are already at their highest. In addition, the forecast decrease in precipitation is greatest in the key May to September period, when precipitation is already at its lowest level, particularly in the southern and northern mountains.
Figure 11. Forecast changes in temperature from 2010 to 2050 for low-impact, medium-impact and high-impact scenarios.
Figure 12. Forecast changes in precipitation for low-impact, medium-impact and high-impact scenarios.

Baseline
These seasonal changes in climate have clear implications for crop and livestock production if no adaptation measures are adopted beyond those that farmers are already employing (such as changing planting dates in response to temperature changes). Forecast climate change impacts on crops if no adaptation measures are implemented are summarised in Table 3.

Source for table 3: “Reducing the Vulnerability of Albania’s Agricultural Systems to Climate Change, IEc 2011

Grapes and olives are forecast to be most affected by climate change, with reductions in grape yield in all agro-ecological zones and olives particularly affected in the intermediate zone. However, increases in yield may occur in the case of winter wheat, as climate change is likely to result in an extended growing season, more moderate autumn and winter temperatures, and greater amounts of precipitation and water availability during the growing season. Alfalfa production should also increase in most regions. The effects on maize vary by region, with increases in the southern highlands and decreases in other regions, probably because current temperatures are most moderate in the southern highlands, thus increases may enhance yields. The other analysed crops should experience only modest crop yield changes relative to current levels.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Coastal lowlands</th>
<th>Intermediate</th>
<th>Northern mountains</th>
<th>Southern highlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa (irrigated)</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Alfalfa (non-irrigated)</td>
<td>-1</td>
<td>-1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Grapes</td>
<td>-8</td>
<td>-10</td>
<td>-6</td>
<td>-10</td>
</tr>
<tr>
<td>Grassland</td>
<td>-2</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Maize</td>
<td>-1</td>
<td>-2</td>
<td>-4</td>
<td>7</td>
</tr>
<tr>
<td>Olives</td>
<td>-1</td>
<td>-8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0</td>
<td>-2</td>
<td>-3</td>
<td>-1</td>
</tr>
<tr>
<td>Watermelons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>4</td>
<td>3</td>
<td>11</td>
<td>8</td>
</tr>
</tbody>
</table>

In contrast, the direct effects of climate change on livestock could be far more severe. Although the available methods for assessing effects on livestock are relatively untested, temperature increases have been shown to decrease livestock productivity.
4. Main conclusions

- All studies carried out to date indicate that the impacts of climate change will be strongly felt in Albania, particularly in the agricultural sector.
- Temperatures will rise and precipitation will become more variable in Albania as a result of climate change.
- The direct effects of climate change on the livestock sector, particularly beef cattle, chickens and sheep, could be substantial, reducing productivity by up to 25 percent by 2050.
- The northern-western part of Albania is highly sensitive to floods and more frequent storms. Unregulated urban development has allowed building right up to the shoreline, exposing infrastructure to a high risk of weather-related damage. Impacts will vary according to the extent of the rise in sea level: the projected rise of 42cm (17 and 80 cm according to minimum and maximum scenarios) by 2100 would flood coastal areas and cause significant saltwater infiltration (UNDP Albania, 2009).
- The direct effects of climate on agricultural yields are related to rainfall, temperature and solar radiation. Storms, heat waves and droughts resulting from changes in the climate are likely to damage agricultural production.
- Albania has not developed any comprehensive adaptation strategy at national or regional level.
- High-priority adaptation measures should include improving drainage; rehabilitating irrigation systems; optimising fertiliser and water application; providing more climate-resilient seed varieties and the know-how to cultivate them effectively for high yields; and encouraging the wider use of hail nets.
- There is a need to increase awareness among decision makers in order to ensure that climate change is included in agricultural sector strategies.

4.1 Albanian capacities to deal with climate variability and climate change

4.1.1 Legal activities
Following the establishment of the first Ministry of Environment in Albania in 2001, the main challenge was to improve the existing legislation, in harmony with EU directives, and to fill the legal gaps in the different environmental fields. Another objective was law enforcement on the part of several institutions and the establishment of new legal structures. No specific law dealing with climate change has been drafted or approved, despite the fact that, during the period of political and economic transformation, a range of acts, regulations and measures indirectly related to greenhouse gas emissions reductions were developed and adopted. These included regulations concerning biodiversity protection, protected areas, waste management, forestry and agriculture.

The Law on Environmental Protection states that the ministry is responsible for the implementation of global environmental agreements in Albania. The Decision of the Council of Ministers on Environmental Monitoring mandates the MEFWA to monitor all environmental issues, including the fulfilment of obligations and the coordination of activities relating to the global environment and to international environmental agreements. The MEFWA collects data from relevant research institutes and line ministries.

No comprehensive national policy to address climate change has been adapted to date in Albania. Mitigation and adaptation measures are addressed through the National Climate Change Action Plan (NCCAP), which comprises a set of priorities for the integration of climate change concerns into other economic development plans.
4.1.2 Monitoring
The main monitoring system in the country was established in 1999 by the Ministry of Environment, which contracts research institutions to collect data each year. Most of those data are related to water resources (quality and quantity), climate, air quality, vegetation and fauna census. There is no monitoring exclusively for climate change purposes, although the gathered data, particularly in relation to surface water and soil, are interpreted in relation to climate change impacts. There is no monitoring of climate change impacts on coastal areas.

The monitoring of meteorological elements in Albania, which provides a valuable source of evidence of climate change and variability, began at the end of the 19th century. It was strengthened in the 1950s to cover the entire territory and to measure an increased number of meteorological elements. After dramatic expansion in the 1980s to around 230 meteorological stations, the national meteorological network in Albania decreased drastically in 1990 and is currently back up to 126 meteorological stations.

The Albanian hydrological network was established in 1949, prior to which there were just four water gauges to measure water level. In 1989, the National Hydrological Network (NHN) comprised 207 stations, 159 of which were on rivers (35 with recorders), 10 on lakes (six with recorders), 32 on springs and irrigation channels, and six on the sea coast and lagoons (all with recorders). The NHN currently comprises 103 stations, 92 of which are on rivers, springs and channels, six on the sea coast and lagoons, and five on lakes. The main parameters monitored are water level, by staff gauges or automatic recording system (15 analogue water-level recorders, five electronic water-level recorders and two data collecting platforms); and river discharge, by flow velocities using current meters. The marine monitoring network measures tides, wind, water temperature and some chemical elements. No recording devices exist at present.

At present, the Institute of Energy, Water and Environment (IEWE) controls the transmission of data from the stations to the collection and processing centre in Tirana. Until 2005, data on extreme temperatures and precipitation were transmitted from some stations on a daily basis by telephone, while monthly data from all stations were sent to the processing centre one month later by mail. Since 2005, the data collection and processing system has apparently been inefficient and is not adequate for weather and extreme climate event predictions, especially for predicting river discharge and the inundation of agriculture land.

4.1.3 Public awareness
Despite increasing public awareness of environmental issues in general, there is still relatively little understanding of climate change in Albania. However, in recent years projects and activities related to climate change issues have helped to raise levels of knowledge and awareness among policy makers and the staff of public institutions.

4.1.4 Plans and programmes
The main climate change programme in Albania is implemented by the United Nations Development Programme (UNDP) in collaboration with the Ministry of Environment, Forestry and Water Administration (www.ccalb.org). The Climate Change Unit is implementing various adaptation-related activities connected to coastal river deltas and energy efficiency.
5. Recommendations

The main recommendations below include measures to be undertaken at national and regional level as well as at farm level.

a. **National level**
   - Integrate climate change in sector and national strategies (National Strategy for Development and Integration; Agriculture Sector Strategy; Inter-sectoral Rural Development Strategy, and local development strategies).
   - Build the capacity of national stakeholders to evaluate the impacts of climate change and develop adaptation strategies at local level.
   - Carry out annual monitoring of climate change.
   - Develop strategies based on climate change scenarios for each agro-ecological zone.
   - Plan for a protection engineering network (seawalls, channels, pumping stations).
   - Build a network of phenological stations based on the agro-ecological zones.
   - Assess water resources taking into consideration climate change scenarios.
   - Prepare a study of erosion and determine the measures to be taken against it.
   - Improving policies for supporting farmers with agricultural inputs (seeds, fertilisers, pesticides, herbicides, seedlings).
   - Improve import and export policies for agricultural products.
   - Improve studies on the cultivation of plants that are resistant to drought.
   - Improve the certification of agricultural products (seeds, seedlings, fruits etc.).

b. **Regional level**
   - Develop strategic plans for local government units or regions based on climate change scenarios.
   - Increase climate-forecasting capacities of trained staff.
   - Carry out crop modelling for the most important crops in the country (including cereals, vegetables, olives and apples) based on climate change scenarios, and update it each year.
   - Improve agricultural extension services applying scientific knowledge in agricultural activities (planting, irrigation, timing).
   - Improve the organisation of farmers’ associations in order to increase their lobbying power.
   - Build capacity to use programmes such as CropWat and AquaCrop in order to improve irrigation efficiency and improve crop yields.
   - Increase levels of education and awareness.
   - Implement permanent monitoring programmes.
   - Build the capacity of agricultural extension services.

b. **Farm level**
   - Improve planting timing, manure management and water-use management.
   - Cultivate plants that are resistant to drought.
   - Improve soil and crop management.
   - Introduce certification of agricultural products (seeds, seedlings, fruits).
   - Improve agro-forestry practices.
   - Maintain irrigation and drainage systems.

6. Literature

The following documents were consulted in the preparation of this report:

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23
Impact of Climate Change on Food Production in Bosnia and Herzegovina

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1. Country overview
Global climate change has a major impact on the environment and sustainable development of Bosnia and Herzegovina. As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP), Bosnia and Herzegovina is obliged, among other things, to develop strategies for climate change mitigation and for adaptation to changing climatic conditions; to cooperate in climate observations, research and technology transfer; and to promote education and public awareness. In this regard, all European countries in transition that are candidates or potential candidates for EU accession have assumed the obligations under the UNFCCC and KP.

Reports by the Intergovernmental Panel on Climate Change (IPCC) emphasise the interdependence of adaptive capabilities and developments, primarily economic, and the need for continued research. Bosnia and Herzegovina belongs among the group of countries sensitive to the negative impacts of global climate change, primarily in relation to agriculture and food production. The country is therefore focusing on the adaptability of agricultural production via measures and programmes related to certain agricultural crops.

Important tasks for the successful adaptation of agriculture to the project impacts of climate change include improving the monitoring of climate and yield; the provision of seasonal climate forecasting and agro-meteorological information for agriculture and forestry; and the provision of information on land-use change in zoning plans.
2. Geographical position and climate

Bosnia and Herzegovina has a total surface area of 51,129 km², and, according to its geographical position in the Balkan Peninsula, belongs to the Adriatic and Black Sea basins. To the north, Bosnia and Herzegovina has access to the river Sava, and to the south to the Adriatic Sea. It is mainly hilly to mountainous, with an average altitude of 500 m (0 m at the seacoast and 2,387 m at the highest peak of the Maglic mountain). Of the total land area, 5 percent are lowlands, 24 percent hills, 42 percent mountains and 29 percent karst area. Forestland covers about 2.5 million ha or 49 percent of the total land area, which is among the highest forest coverage in Europe (Spasova et al., 2007).

![Figure 1. The geographical position of Bosnia and Herzegovina in Europe](image)

The general atmospheric circulation and air mass flow, the dynamic relief, the orientation of mountain ranges, the hydrographical network and the vicinity of the Adriatic Sea have all created conditions for a wide spectrum of climate types. These include temperate continental climate, represented mostly in the northern and central parts of the territory; sub-mountainous and mountainous climate (represented on over 1,000 m), and Adriatic (Mediterranean) and modified Adriatic climate, represented in the coastal area of Neum, in the lowlands of Herzegovina.

3. Agricultural characteristics

Of the total land area in Bosnia and Herzegovina, about 2.6 million ha are suitable for agriculture, only 0.65 percent of which is irrigated. This small percentage of irrigated land is the result of an undeveloped irrigation infrastructure. Fertile lowlands comprise 16 percent of agricultural land.
in Bosnia and Herzegovina, 62 percent is less fertile hilly and mountainous areas, while the Mediterranean area accounts for 22 percent (INC, 2009).

Of the total territory of Bosnia and Herzegovina, amounting to 5,112,879 ha, the Federation of Bosnia and Herzegovina (FBiH) covers 2,607,579 ha, while Republika Srpska (RS) takes up 2,505,300 ha.

Based on population figures and the breakdown of farmland utilisation (see table 1), it can be stated that in the Federation of Bosnia and Herzegovina there are 0.56 ha of farmland per capita (0.23 ha of ploughed land and vegetable gardens), while the situation in Republika Srpska is somewhat better, at 0.90 ha of farmland per capita, or 0.46 ha of ploughed land and vegetable gardens (NEAP BiH, 2003).

| Table 1. Bosnia and Herzegovina land utilisation overview (FBiH and RS) |
|----------------|----------------|----------------|----------------|
|                | ha              | ha              | FBiH          | RS          |
| Total area     | 2,607,579       | 2,505,300       | 51.0          | 49.0        |
| Woodland and bare rocky ground | 1,348,783 | 1,206,681       | 52.8          | 47.2        |
| Farmland       | 1,258,796       | 1,298,619       | 49.2          | 50.8        |
| Ploughed land and vegetable gardens | 508,062 | 671,599         | 43.1          | 56.9        |
| Plant crops    | 461,360         | 616,548         | 42.8          | 57.2        |
| Orchards       | 41,395          | 54,358          | 43.2          | 56.8        |
| Vineyards      | 5,307           | 693             | 88.5          | 11.5        |
| Meadows        | 248,291         | 236,922         | 51.2          | 48.8        |
| Pastures       | 502,443         | 358,734         | 58.3          | 41.7        |
| Farmland per capita | 0.56    | 0.90            |               |             |
| Ploughed land and vegetable gardens per capita | 0.23    | 0.46            |               |             |


In Bosnia and Herzegovina, over 95 percent of land is privately owned. In lowland areas, natural conditions are favourable for sustainable agricultural production and a modern market economy. The highest-quality soils are to be found in the valleys of the rivers Sava, Una, Sana, Vrbas, Bosna and Drina. These valleys are suitable for the sustainable production of cereal crops (wheat, barley, soybeans, corn); the breeding of cattle in barns; and the large-scale growing of fruits (apples, plums, pears), vegetables, medicinal herbs and industrial crops (WSSD, 2002).

In the highlands of Bosnia and Herzegovina there is agricultural land suitable for cattle breeding and complementary agricultural production, the production of crops for human consumption, animal feed production, the production of barley for breweries and potato growing.

Agricultural land in the Mediterranean region covers the territory of the southern Dinaric Alps and the lowlands of the Herzegovina region. Karstic fields in this area cover about 170,000 ha. This land is potentially suitable for intensive greenhouse and open-space agricultural farming, vine
growing, the large-scale growing of citrus fruits and vegetables, freshwater fish farming and beekeeping.

Over 30 percent of the sub-Mediterranean area is classified as highland pasture, suitable for raising small animals (goats, sheep and cattle). There is a strong need to intensify agricultural farming in Bosnia and Herzegovina, bearing in mind that the agricultural sector is currently producing less than half the food required by the domestic population. At present, foodstuffs account for over half of the total value of the country’s imports.

The erosion and flooding of farmlands in Bosnia and Herzegovina are endangering harvests and the sustainable use of soil. Lijevce polje, Semberija, and the fertile farmland along the rivers Drina, Bosna, Vrbas, Sana, Una, Sava, Neretva and Trbisnjica, are under threat (INC, 2009).

4. GHG emissions

One of the key commitments in the development of the Initial National Communication (INC) was the creation of an inventory of GHG emissions for the reference year 1990. Total emissions of CO₂ equivalents in Bosnia and Herzegovina in 1990 amounted to 34,043.49 gigagrams (Gg). The collected data indicate that the major source of CO₂ emissions is the energy sector, which contributes 74 percent, followed by agriculture (12 percent), industrial processes (11 percent) and the waste sector (3 percent), as shown in figure 2. Other sources include agriculture, industrial processes and waste. The main sources of methane are agriculture (livestock), uncontrolled (fugitive) emissions from coal mining and waste disposal. The largest volume of N₂O emissions comes from agricultural soil as a result of crop cultivation. It is also important to note that, according to the INC, forests in Bosnia and Herzegovina represent an important sink for CO₂, at 7,423.53 Gg of CO₂ for the reference year 1990 (INC, 2009).

Figure 2: Share of CO₂ equivalent emissions by sector
Emissions of CO₂ equivalents from agriculture are made up of methane (CH₄) and nitrous oxide (N₂O). Total emissions of CO₂ equivalents in the inventory for the INC were 4,084 Gg (see figure 3).

The agricultural sector in Bosnia and Herzegovina contributes 1,833.51 Gg of CH₄ emissions of CO₂ equivalent. Methane is formed as a direct product of a herbivore’s metabolism (gut fermentation) and as a result of the organic decomposition of animal waste (manure). The IPCC methodology is determined by methane emissions for each type of animal (dairy cows, other cattle, sheep, horses, pigs and poultry).

The most important source of N₂O in Bosnia and Herzegovina is agriculture. Many agricultural processes utilise nitrogen in the soil, thus increasing the available nitrogen for nitrification and denitrification, which has an impact on emissions of N₂O. The methodology distinguishes three sources of N₂O emissions: direct emissions from agricultural soils; emissions as a result of animal activities; and emissions indirectly caused by agricultural activities. Of these, the largest volume of emissions comes directly from agricultural soils, the treatment of soil, and crop cultivation. This includes the application of mineral fertilisers, nitrogen from manure, the cultivation of pulses and soybeans (which fix nitrogen in the soil), and nitrogen from agricultural crop residues and the processing of peat (INC, 2009).

![Figure 3. Percentage of CO₂ Equivalent Emissions](source: INC, 2009)

(series 1 = Energy
series 6 = Industry)
5. Climate Conditions in Bosnia and Herzegovina

5.1 Temperature

Based on temperature characteristics, the territory of Bosnia and Herzegovina may be divided into three temperature zones: warm, moderate and cold. The warm zone covers the Adriatic coast and lowland Herzegovina, where summers are hot and winters very mild. Mean winter temperatures are above 5°C, and summer temperatures reach 40°C (in Mostar, Trebinje and Capljina). Mean annual temperatures have a value of above 12°C.

Moderate areas include plains and hilly regions in the central part of Bosnia and Herzegovina, where summers are warm and winters are moderately cold. Mean winter temperatures here are around 0°C and summer temperatures reach 35°C (Banja Luka, Bijeljina, Sarajevo and Tuzla). The mean annual temperature is between 10°C and 12°C, while in areas above 500 m it is below 10°C.

The cold zones are mountainous areas where summers are fair (days moderately warm and nights chilly), and winters very cold. During the last three months of the year, the mean temperature is lower than 0°C (Bjelasnica, Sokolac and Kupres) (see figure 4).

Fig. 4. Spatial distribution of mean annual air temperatures in Bosnia and Herzegovina, 1961-1990.
Source: Faculty of Natural Science, University of Banja Luka

Air temperature monitoring in the period 1999 to 2008 indicates that a rising trend is evident over almost the entire territory of Bosnia and Herzegovina. In northern and northwestern Bosnia and Herzegovina, the mean annual air temperature had a value of over 12°C in this period. In the central,
mountainous region, the mean annual temperature is similar to the values for the period 1961 to 1990. In southeastern Herzegovina, the trend is a slight decrease in mean annual temperature (see figure 5).

![Fig. 5. Spatial distribution of mean annual air temperatures in Bosnia and Herzegovina, 1999-2008.](image)

Source: Bajic, D, Faculty of Natural Science, University of Banja Luka, 2011.

Figure 6 shows changes in mean annual temperature based on a comparison of the two observed periods (1999-2008 and 1961-1990). The biggest increases in temperature are in the northwest and northeast, where values are higher by up to 2°C per year. In the lowlands of Herzegovina, there is a slight increase of 1°C per year. However, in the highlands, there is a slight decrease in temperature. The differences have not been explained scientifically and may be caused by the different climate regimes in these regions.
5.2 Precipitation

The quantity of rainfall in Bosnia and Herzegovina is affected by the humid air mass coming from the west (Atlantic Ocean) and south (Adriatic Sea). From the west (where mountainous areas receive around 2,000 mm per year) the total quantity of rainfall decreases to around 700 mm towards the east (Bijeljina). Maximum rainfall in northern Bosnia and Herzegovina occurs most often in June or September. Herzegovina and the highest central parts of Bosnia and Herzegovina are mainly exposed to the humid air mass from the south: they are characterised by a maritime pluviometric regime and receive up to 2,000 mm of rainfall annually. Maximum rainfall occurs mostly in November/December.

Data for two distinct periods were used in order to analyse changes in precipitation in the territory of Bosnia and Herzegovina. The first period (1961-1990) was related to the standard World Meteorological Organization (WMO) climate normal; and the second (1999-2008) was a period in which the IPCC concluded that there was a major reduction in the amount of rainfall per annum for Southern Europe.

The analysis indicates that the central mountainous and central northern parts of Bosnia and Herzegovina tend to have an annual increase in rainfall on a seasonal basis. The biggest increase in rainfall was recorded in Sokolac (15.2 percent per annum compared to the reference year) and Doboj (12.8 percent per annum). There is also a slight annual increase in rainfall in Bijeljina and Banja Luka. The comparative analysis shows that the greatest decrease in annual rainfall was recorded in
Herzegovina (Mostar and Bileca). However, it is important to bear in mind that this is the rainiest area in Bosnia and Herzegovina and the region, where annual rainfall exceeds 1,500 mm per year, and the observed decrease is not likely to affect annual water balance. When observing changes in the precipitation regime in Bosnia and Herzegovina by season, it is clear that the greatest changes are during the autumn, when an increase is recorded at all stations except Mostar (Figure 7). The biggest increase was in Doboj (30.6 percent compared to the reference period) and Sokolac (25.4 percent), while in Mostar there was a reduction of 6.2 percent (Trbic et al., 2010).

The biggest deficit in rainfall during the summer period, and the biggest changes, were recorded in Livno (-21.4 percent), Bileca (-20.5 percent), Bihac (-17.0 percent), Gacko (-12.6 percent), Banja Luka (-12.0 percent), Mostar (-11.7 percent) and Prijedor (-11.7 percent). As mentioned above, in Sokolac and Doboj there is an excess during the summer period caused by the area’s geographical position. Reduced rainfall followed by higher temperatures during summer in the territory of Bosnia and Herzegovina causes increases in the intensity and frequency of dry periods. The problem of drought in Bosnia and Herzegovina is complex and requires additional research, including the monitoring of rainfall and drought series and their consequences for agriculture, forestry and hydro potential.

There is a pronounced deficit in spring precipitation in Herzegovina (Mostar -16 percent, Ivan Sedlo -11 percent). Winter precipitation is in excess, with the biggest increase in Sokolac (21.4 percent) (figure 7).

Rainfall levels and their spatial distribution (figure 8) indicate that the earlier projection by the IPCC for this part of Eastern Europe is not applicable. Our research also suggests the need to modify the calibration models for the IPPC region of South Eastern Europe in terms of the variability of rainfall estimates, based on the latest official data.
5.3 Extreme climate events

Levels of probability for extreme temperatures were calculated from the maximum annual average temperature over the period 1950 to 2008 (Banja Luka) and 1888 to 2008 (Sarajevo). The Gumbel distribution extreme value theory ($T_{max}(t) = T_m + \left(\frac{\ln N}{g}\right)$) was used to estimate the return period, that is, the theoretical distribution function in the future. In Banja Luka, the value of $T_{max} = 41.4^\circ$C, observed in 1957 and 2007. The return period is calculated as 59 years, with a probability of 3 percent. In Sarajevo, the value of $T_{max} = 40^\circ$C and was observed for 1946. The return period was calculated at 122 years, with a probability of 0.82 percent. Although the probability of extreme temperatures is low, it is still evidence of the problem — that is, during the period 1999 to 2008 there is a clear increase in the number of days with tropical temperatures ($T_{x}>30^\circ$C) compared to the period 1961 to 1990, while the number of days with extreme temperatures is below the calculated average.
Mean annual temperature in the territory of Bosnia and Herzegovina has risen over the last 100 years by about 0.6°C (Majstorovic et al. 2008). Trends differ according to season: the latest trends show an increase during summer and winter, due also to the impact of urban systems and the urban heat island effect. Bearing in mind the geographical position of Bosnia and Herzegovina, the fact that current changes are not as dramatic as in some other parts of the world (INC, 2009), and the research data and trends recorded at weather stations in the country for the INC, the expert group chose the B2 climate change scenario based on temperature and precipitation data for the
periods 1961 to 1990 and 1999 to 2008. However, during the preparation of the Second National Communication (SNC) to the UNFCCC, the development of climate models and climate change scenarios was envisaged. It is expected that the SNC will include new findings for the region as a result of regional cooperation.
6. Impacts of climate change on food production

6.1 Agro-ecological conditions

The lowland areas of Bosnian Posavina, with altitudes of up to 400m, have the most suitable ecological conditions for growing corn and wheat. Hybrids can be cultivated here during the entire growing season when there is a sufficient temperature sum (2,800 to 3,000°C). In the leaf-growing stage of corn crops, large amounts of water are needed per unit area, even when the transpiration coefficient is not large. Corn is able to use water economically, depending on the growing conditions. The amount of water taken up by corn plants from the soil through the roots reaches up to 200 litres. During the growing season, most water (as much as 4 litres a day) is consumed during the intense growth and reproduction phase. Critical periods in terms of water supply are the silking stage and panicle phase. Water demand for corn growing in the Bosnian Posavina is about 450mm of water during the growing season. Maximum water demand is in June and July.

The highest wheat yields and the best-quality wheat are achieved in regions with a total rainfall of between 650 and 750l/m². In most of Bosnia and Herzegovina’s agricultural regions the total rainfall is below this figure, firstly due to the uneven distribution of rainfall, and secondly due to high evaporation rates. By using different agricultural practices (e.g. appropriate ploughing depth and sowing preparation) it is possible to ensure a better water supply for wheat crops and the rational use of water during the growing season. Lack of moisture in the elongation phase is a particular threat because at this stage lack of moisture disrupts the relationship between leaf area and actively absorbing root surface. Lack of moisture in the soil during flowering and heading further increases the number of infertile ears. The extent of infertility sometimes reaches 100%. Critical periods in terms of moisture are the sowing and germination periods, and in arid regions the soil should be watered before sowing where possible.

The ratio of wheat yield to drought is related to the phylogenetic development of some types of wheat in arid regions. Drought conditions in the arid region of Bosnia and Herzegovina occur mainly in the second part of the growing season. Soil drought and atmospheric drought are highly interrelated. The maximum reduction in yield is observed in the case of dry soil in the elongation phase of intensive growth, with a slightly smaller reduction in the heading stage. When the soil is dry in the tillering stage, the negative impact on the milk stage is not as pronounced. When the soil is dry in the heading stage, grain yield is reduced by 45 to 50 percent, and sometimes even more. Drought during the milk stage is better tolerated than in the heading stage.
6.2 Impact of drought on corn yields

Drought is a harmful weather event that results from the prolonged absence of rainfall. In combination with other meteorological factors such as high temperatures and winds, drought leads to dry surface soil that may cause serious problems for plants in terms of water balance. This results in a stress reaction in corn plants, and significant reductions in yield. There are several models for the classification of drought and weather conditions during the corn-growing season. In the present study, the Seljaninov hydrothermal coefficient (HTK) was used. Data were used from meteorology stations located in northern Bosnia and Herzegovina.

Seljaninov hydrothermal coefficient:

\[
HTK = \frac{10 \cdot \sum_{i=1}^{n} H_i}{\sum_{i=1}^{n} t_i (t > 10^0 \degree C)}
\]

where \( \sum_{i=1}^{n} H_i \) is the amount of rainfall in the growing season and \( \sum_{i=1}^{n} t_i \) is the calculated mean daily temperature for the growing season (April to September).

**Modified climatic classification according to Seljaninov**

<table>
<thead>
<tr>
<th>HTK mm/°C</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.5</td>
<td>Dry</td>
</tr>
<tr>
<td>0.5–0.7</td>
<td>Very dry</td>
</tr>
<tr>
<td>0.7–0.9</td>
<td>Arid</td>
</tr>
<tr>
<td>1.0–1.3</td>
<td>Insufficient humidity</td>
</tr>
<tr>
<td>1.3–1.5</td>
<td>Moderately humid</td>
</tr>
<tr>
<td>1.5–2.0</td>
<td>Humid</td>
</tr>
<tr>
<td>2.0–3.0</td>
<td>Very humid</td>
</tr>
<tr>
<td>&gt;3.0</td>
<td>Excessive humidity</td>
</tr>
</tbody>
</table>

**Table 2. Climatic classifications according to the Seljaninov hydrothermal coefficient for the growing season, 2003 to 2007**

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>2003 (April - September)</th>
<th>2004 (April - September)</th>
<th>2005 (April - September)</th>
<th>2006 (April-September)</th>
<th>2007 (April - September)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HTK mm/°C</td>
<td>Characteristic</td>
<td>HTK mm/°C</td>
<td>Characteristic</td>
<td>HTK mm/°C</td>
</tr>
<tr>
<td>Prijedor</td>
<td>0.8</td>
<td>Arid</td>
<td>1.6</td>
<td>Humid</td>
<td>1.7</td>
</tr>
<tr>
<td>Banja Luka</td>
<td>1.0</td>
<td>Insufficient humidity</td>
<td>1.8</td>
<td>Humid</td>
<td>2.0</td>
</tr>
<tr>
<td>Doboj</td>
<td>0.9</td>
<td>Arid</td>
<td>2.2</td>
<td>Very humid</td>
<td>2.2</td>
</tr>
<tr>
<td>Gradiska</td>
<td>0.8</td>
<td>Arid</td>
<td>1.2</td>
<td>Insufficient humidity</td>
<td>1.3</td>
</tr>
<tr>
<td>Bijeljina</td>
<td>0.6</td>
<td>Very dry</td>
<td>1.6</td>
<td>Humid</td>
<td>1.7</td>
</tr>
</tbody>
</table>

*Source: Republic Hydrometeorological Institute of Republika Srpska*
Based on Table 2, it can be concluded that in 2003 the growing season was extremely dry, especially during the summer. Lack of rainfall and high temperatures caused a low Seljaninov coefficient or the occurrence of drought. Drought had a negative impact on yields of corn and wheat, as confirmed by an analysis of correlations between rainfall and yield.

### Table 3. Climate classifications according to the Seljaninov hydrothermal coefficient for the summer period, 2003 to 2007

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>2003 (June - August)</th>
<th>2004 (June - August)</th>
<th>2005 (June - August)</th>
<th>2006 (June - August)</th>
<th>2007 (June - August)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HTK mm/°C Characteristic</td>
<td>HTK mm/°C Characteristic</td>
<td>HTK mm/°C Characteristic</td>
<td>HTK mm/°C Characteristic</td>
<td>HTK mm/°C Characteristic</td>
</tr>
<tr>
<td>Prijedor</td>
<td>0.6</td>
<td>Very dry</td>
<td>1.2</td>
<td>Insufficient humidity</td>
<td>1.8</td>
</tr>
<tr>
<td>Banja Luka</td>
<td>0.6</td>
<td>Very dry</td>
<td>1.5</td>
<td>Moderately humid</td>
<td>2.1</td>
</tr>
<tr>
<td>Doboj</td>
<td>0.9</td>
<td>Arid</td>
<td>1.8</td>
<td>Humid</td>
<td>2.6</td>
</tr>
<tr>
<td>Gradiška</td>
<td>0.6</td>
<td>Very dry</td>
<td>1.1</td>
<td>Insufficient humidity</td>
<td>1.3</td>
</tr>
<tr>
<td>Bijeljina</td>
<td>0.6</td>
<td>Very dry</td>
<td>1.3</td>
<td>Moderately humid</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Source: Republic Hydrometeorological Institute of Republika Srpska.

Precipitation during the vegetation period undoubtedly has a significant effect on corn yield. While it is not the only factor in yield formation, an analysis of the correlation between rainfall and yield indicates a very strong direct linear relationship between the two, which is referred to as the p-value (i.e. the relationship between yield in t/ha and precipitation for a selected period).

Testing of the assessed simple linear correlation coefficient to obtain p-value = 0.00759 (0.00759 <0.01) for the period April to September, and p-value = 0.02768 (0.02768 <0.05) for the period June to August, indicates that precipitation statistics significantly affect yield and are one of the key factors for achieving high yields (see table 4).

### Table 4. Correlation between rainfall and average corn yield.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Year</th>
<th>Linear coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2003</td>
<td>2004</td>
<td>2005</td>
</tr>
<tr>
<td>Precipitation (IV-IX)</td>
<td>292.9</td>
<td>562.0</td>
<td>583.9</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>2.77</td>
<td>5.36</td>
<td>5.33</td>
</tr>
<tr>
<td>Precipitation (VI-VIII)</td>
<td>143.8</td>
<td>267.6</td>
<td>370.3</td>
</tr>
</tbody>
</table>

Source: Republic Hydrometeorological Institute of the Republika Srpska.

---

1 Ideal p-value for period April to September, p-value = 0.01
2 Ideal p-value for period June to August, p-value = 0.05

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Since precipitation is important in the formation of high yields, and since it is not possible to affect levels of precipitation, it can be concluded that the provision of irrigation, the selection of hybrids resistant to drought, and the prediction of water need are essential in order to ensure stable and continuous corn yields in Bosnia and Herzegovina. In 2003, when a severe drought occurred, the wheat yield was 2.5 t/ha. During 2004, there was no drought and the wheat yield increased to 5.8 t/ha.
7. Recommendations for decision making based on research findings

In recent decades, the impacts of climate change have been significant globally and in South Eastern Europe, including Bosnia and Herzegovina. Projections by the IPCC, local experts and research indicate the significant impacts of climate change on agriculture, the environment and food production in Bosnia and Herzegovina. The present study shows a clear link between lack of rainfall during the vegetation period, the occurrence of drought and yields of corn and wheat. In this context, urgent measures are needed on the part of policy makers in order to reduce the impact of climate change and improve capacity for adaptation. Listed below are problems and barriers, as well as recommended measures and action for policy makers.

**Problems and barriers:**

- Weak national capacity for comprehensive quantitative and qualitative vulnerability and adaptation (V&A) assessment.
- Inadequate representation of the problem of climate change in entity strategies for agricultural development, rural development and irrigation projects.
- Insufficient network of meteorological and agro-meteorological stations.
- Poor data on adaptation options and lack of mechanisms for information sharing and management across the agriculture sector.
- Limited awareness of climate change adaptation among stakeholders and the population.
- Insufficient and limited funding for adaptation studies.
- Inadequate education for farmers on sensitive climate change issues.

**Priority measures:**

- Drafting a strategy and action plan for climate change adaptation in Bosnia and Herzegovina.
- Improving the weather and climate monitoring database.
- Developing climate change scenarios and models by 2100.
- Carrying out a detailed analysis of institutional, legal, organisational, financial and human resources needs in order to develop capacity to implement the UNFCCC and Kyoto Protocol.
- Collecting information on good practices in transition countries and developed countries in the European Union that have adopted strategies and action plans for the implementation of the UNFCCC and the Kyoto Protocol.
- Creating mechanisms to monitor the implementation of the INC under the UNFCCC.
• Involving local communities in activities related to climate change adaptation, in recognition of the fact that they are the primary end users of most adaptation activities.
• Undertaking research on the development of drought-resistant varieties and crops.
• Improving early warning and response systems.
• Preparing the SNC to the UNFCCC.
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Impact of climate change on food production and selected crop yield in Croatia

Hana Mesić, dipl.ing.

Introduction

The agricultural sector in Croatia has undergone changes during the last two decades as a result of changes in the country’s political and economic conditions. In addition, the lives of Croatian farmers have been further affected by the impacts of climate change and alterations in weather conditions. The appearance of dry periods with unexpectedly high air temperatures, sometimes followed by periods of high rainfall, floods, hail, strong winds and late spring frosts, represents a new reality for Croatian farmers. Such phenomena are not new, but they are becoming increasingly frequent. Although it is not possible to predict all the future weather patterns that will affect the agricultural sector, estimates can be made on the basis of existing climate change scenarios.

1. Brief overview of country conditions

According to data from the Croatian Bureau of Statistics (Croatia in Figures, 2010[http://www.dzs.hr/Hry_Eng/CroInFig/hrvatska_u_brojKama.pdf]), the Republic of Croatia covers a land area of 56,594 km$^2$. The estimated population in the second half of 2009 was 4,429,000, with a population density of 78.3 people per km$^2$. According to the most recent census (carried out in 2001), 56 percent of inhabitants live in urban areas. The 2005 birth rate was 9.6 percent, with a decreasing population rate (-2.1 percent). Based on information published in the European Environment State and Outlook Report 2010 ([http://www.eea.europa.eu/soer/countries/hr/](http://www.eea.europa.eu/soer/countries/hr/)), the total population of Croatia is predicted to be 3.68 million by 2050, with 80 percent of the population living in urban areas.

1.1. Croatian economic conditions

At the beginning of 2011, the Croatian economic situation cannot be described as very optimistic. The unemployment rate is high (at over 300,000 people), and exports have decreased in the last few years. As a result of the high fiscal deficit there is a continuous
need for foreign loans. Croatia is still struggling with the crisis and has negative GDP growth. Gross domestic product per capita in 2009 was EUR 10,246; the average monthly gross salary was around EUR 1,000; and the average monthly net salary slightly higher than EUR 700. The import export coverage rate in 2009 was 49.5 percent.

1.2. Geographic conditions

Based on geographic conditions, Croatia can be divided into three regions: Pannonian, mountainous and Mediterranean. Lowland areas, up to 200 m above sea level, make up 53 percent of the territory; hilly areas and hill slopes between 200 and 500 m above sea level make up 26 percent; and highland and mountainous regions over 500 m above sea level make up 21 percent. Land assets include 1,242 islands and islets, as well as almost 4,000 km of rivers and 5,900 m$^3$ of renewable drinking water per capita a year. The karst region occupies about 54 percent of the territory. Karst phenomena and forms are mainly found in the limestone of highland and coastal Croatia.

According to Basic et al. (2004), land is an essential Croatian national asset and resource, and, following the division of the country into three geomorphological and climatic units, the agricultural regions can also be divided into Pannonian, mountainous and Mediterranean regions, each of which has specific agricultural conditions. In order to achieve a better understanding of the specific production conditions, the three regions are divided into sub-regions (see figure 1).

Figure 1 – Agricultural regions in Croatia
Agricultural land covers a significant proportion of Croatian territory, although there is a difference of 1 million hectares between the data obtained using the method of agricultural land determination of the European Commission programme Coordination of Information on the Environment (CORINE) and the statistical land-use data taken from the Statistical Yearbook (figure 2) and the data from the Corine Land Cover project (CLC) (table 1). This difference is the result of the methodology employed for collecting data on agricultural land use in Croatia. While the CLC data are obtained from the detailed analysis of satellite images, the statistical information is based on land-use data from registered agricultural farms and companies.

Figure 2 – Agricultural land and arable land and permanent crops in Croatia, 1996-2008
Table 1 shows the categories of agricultural land use in Croatia according to data obtained using the CLC method.

Table 1 – Agricultural land use in Croatia according to CLC classes, 1980-2006

<table>
<thead>
<tr>
<th>CORINE class</th>
<th>Description</th>
<th>1980</th>
<th>1990</th>
<th>2000</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>211</td>
<td>Non-irrigated arable land</td>
<td>385,633</td>
<td>378,430</td>
<td>368,974</td>
<td>370,262</td>
</tr>
<tr>
<td>212</td>
<td>- Permanently irrigated land</td>
<td>9,443</td>
<td>9,397</td>
<td>9,821</td>
<td>9,821</td>
</tr>
<tr>
<td>221</td>
<td>- Vineyards</td>
<td>28,200</td>
<td>28,193</td>
<td>28,925</td>
<td>29,055</td>
</tr>
<tr>
<td>222</td>
<td>- Fruit trees and berries</td>
<td>9,760</td>
<td>9,410</td>
<td>9,548</td>
<td>9,574</td>
</tr>
<tr>
<td>223</td>
<td>- Olive groves</td>
<td>18,759</td>
<td>18,705</td>
<td>20,223</td>
<td>20,197</td>
</tr>
<tr>
<td>231</td>
<td>- Pastures</td>
<td>475,815</td>
<td>477,566</td>
<td>307,296</td>
<td>298,950</td>
</tr>
<tr>
<td>242</td>
<td>- Complex cultivation patterns</td>
<td>1,034,844</td>
<td>1,026,779</td>
<td>1,017,238</td>
<td>1,022,051</td>
</tr>
<tr>
<td>243</td>
<td>- Land principally occupied by agriculture, with significant areas of natural vegetation</td>
<td>515,282</td>
<td>510,822</td>
<td>523,509</td>
<td>524,202</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>2,477,736</td>
<td>2,459,302</td>
<td>2,285,534</td>
<td>2,284,112</td>
</tr>
</tbody>
</table>

Source: CEA, CLC database 2006

Figure 3 shows the spatial distribution of agricultural lands according to data obtained using the CLC method.

Figure 3 – Map of agricultural land use in Croatia using the CLC method
1.3. Role of agriculture/food production

According to World Trade Organization’s Trade Policy Review Business Briefing 2010 (http://www.intracen.org/btp/wtn/newsletters/2010/tpr_croatia.htm), agriculture, hunting, forestry and fishing contribute around 7 percent to GDP, 10 percent to employment and 13 percent to merchandise exports in Croatia. One of the important problems in the agricultural sector in Croatia is related to structure: farms are small and are very often divided into several plots. This can cause numerous problems in the organisation of work as a lot of time is spent on transportation and on unproductive activities. The most important crops are corn, winter wheat, other cereals, followed by industrial crops such as sugar beet, oilseed rape and sunflowers.

1.4. Greenhouse gas emissions in Croatia

The general decline in economic activity during the war in Croatia between 1991 and 1995 resulted in a reduction in total greenhouse gas (GHG) emissions. Following the war, emissions began to rise again at an average rate of 3 percent per annum, with the biggest contribution from the energy, industrial processes and waste sectors. Total GHG emissions in 2008 expressed as CO$_2$ equivalents, including removals by sinks, was 31,132 gigagrams
(Gg) of CO\textsubscript{2} equivalents, which represents a reduction of 2 percent compared to 1990 GHG emissions (CEA, 2011).

The energy sector is the biggest contributor to GHG emissions, followed by industrial processes and agricultural activities (figure 4). The share of agriculture out of total GHG emissions varied between 13.9 percent in 1990 and 10.8 percent in 2008.

Figure 4 – GHG emissions in Croatia, 1990, 1995, 2000-2008, Gg CO\textsubscript{2} eq.

Agricultural activities contribute directly to GHG emissions, although there is great potential for reducing them. Methane (CH\textsubscript{4}) and nitrous oxide (NO\textsubscript{2}) are the primary greenhouse gases emitted by agricultural activities.

Methane is a direct product of animal metabolism and is generated during the digestion process. The biggest producers of methane as a result of enteric fermentation are ruminants (cows, cattle and sheep). The amount of methane produced and excreted depends on the animal’s digestive system and the amount and type of feed. Dairy cattle represent more than 50 percent of the total CH\textsubscript{4} emissions from enteric fermentation, followed by non-dairy cattle, which represent around 30 percent of the total CH\textsubscript{4} from enteric fermentation. Methane is also generated from the anaerobic decomposition of manure. Manure storage methods in which anaerobic conditions prevail (liquid animal manure in septic tanks) are favourable for the anaerobic decomposition of organic substances and the release of methane.
Emissions of nitrous oxide (N\textsubscript{2}O) from all animal waste management systems include emissions from anaerobic lagoons, liquid systems, solid storage, dry lots and other systems. Direct emissions of N\textsubscript{2}O from agricultural soils include the total amount of nitrogen applied to soils through cropping practices, among which are the application of synthetic fertilisers, nitrogen from animal waste, the production of nitrogen-fixing crops, nitrogen from crop residue mineralisation, and soil nitrogen mineralisation due to the cultivation of histosols. Calculations of indirect N\textsubscript{2}O emissions from nitrogen use in agriculture are based on two pathways: volatilisation and the subsequent atmospheric deposition of NH\textsubscript{3} and NO\textsubscript{x} (originating from the application of fertilisers and animal manure); and leaching and runoff of nitrogen applied to or deposited on soils.

Methane emissions from enteric fermentation and manure management represented 41 percent of the total CH\textsubscript{4} emissions from anthropogenic activities in 1990. From among domestic animals, dairy cattle were by far the largest emitters of methane. Agricultural soil management activities, such as fertiliser application and other cropping practices, were the largest sources of N\textsubscript{2}O emissions in Croatia, accounting for 70 percent of total emissions.

2. National climate projections up to 2020, 2050 and 2100

2.1. Global models

Based on climate change scenarios according to the IPCC methodology for Croatia, changes in mean annual air temperature and changes in rainfall were predicted (scenario IS92a and IS92e, http://sedac.ciesin.columbia.edu/ddc/is92/index.html). According to the SRES GCM (IPCC), air temperature (°C) relative to the mean temperature for the period 1961 to 1990 will increase by between 1 and 2°C by 2020; by between 2 and 3°C by 2050; and by between 3 and 4°C by 2080 (figures 5, 6 and 7).

Figure 5 – Annual mean temperature change in the 2020s relative to the 1961-1990 average
Figure 6 – Annual mean temperature change in the 2050s relative to the 1961-1990 average

Source: Based on IPCC-DDC data; SRES GCM change fields (IPCC 2001) http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf

Figure 7 – Annual mean temperature change in the 2080s relative to the 1961-1990 average

Source: Based on IPCC-DDC data; SRES GCM change fields (IPCC 2001) http://www.ipcc-data.org/cgi-bin/ddcvis/gcmcf
2.2. Regional models

According to information published in the Fifth National Communication of the Republic of Croatia under the United Nations Framework Convention on Climate Change (NC5 UNFCCC), the results of the RegCM regional climate model integrations were analysed for all seasons from the two 30-year periods: 1961-1990 (representing the present climate), and 2041-2070 (representing future climate projections according to the IPCC A2 scenario). According to the IPCC Special Report on Emissions Scenarios (SRES http://www.grida.no/publications/other/ipce_tar/?src=/climate/ipce_tar/wg1/029.htm), “The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.” For all seasons, RegCM predicts a surface temperature increase within the entire integration domain, as well as throughout the depth of the model atmosphere. According to the same source, a decrease in total precipitation in the future climate is expected over a large part of the year, primarily in Croatia’s littoral zone and its surroundings. In relative terms, this
decrease will be biggest in summer. In winter, there will be a slight increase in precipitation, again in a narrow littoral zone, although the increase is not statistically significant. In northern Croatia, no significant changes in precipitation are expected in the future climate.

3. Impacts of projected climate conditions on food production in Croatia

The impacts of climate change on the various agricultural crops that are grown in Croatia can be analysed as being potentially beneficial or adverse. Sostaric et al. (2002) presented research results including analyses of precipitation, air temperature and evapotranspiration during the vegetation period and annually between 1961 and 2000 for eastern Croatia. The analysis of basic climatic data revealed that dry years were more common after 1981. Changes in climate after 1981 were reflected through reduced precipitation, relative air humidity and higher air temperatures. The increased reference evapotranspiration (ETo), especially over dry years, resulted in increased crop water demand during the vegetation period.

Research has been carried out in Croatia on the yield stability of winter wheat under water stress conditions (Baric et al. 2008). Data for yield and other agronomic traits were collected from field trials comprising 40 winter bread wheat genotypes (T. aestivum L.) grown in non-limited water conditions and with a water deficit during the typical grain-filling period for the Mediterranean region. Genotypes responded differently to water deficit, showing a decrease in yield of between 14 and 50 percent compared to non-limited water conditions. For genotypes with high mean productivity (> 7 t ha⁻¹), losses in stress conditions ranged between 1.3 and 3.0 t ha⁻¹. Reductions in yield due to water stress were 29, 37 and 46 percent for early-, mid- and late-maturing genotypes respectively.

Drought is one of the most important environmental stresses affecting agricultural productivity and can result in considerable yield reduction. Keresa et al. (2008) studied tolerance to drought stress in winter wheat at seedling stage. They examined the reaction of 26 winter wheat genotypes (T. aestivum L.). Drought stress at -0.5 and -1.0 megapascals (MPa) of water potential was simulated with polyethylene glycol 8000. According to root fresh weight (RFW), shoot fresh weight (SFW) and the ratio of RFW to SFW, all expressed as a percentage of the control average, and the shoot dry weight (SDW) of nine-day-old
seedlings, genotypes tolerant to drought stress at seedling stage were identified. Tolerance at the seedling stage showed significant correlation with tolerance to drought stress at the heading and grain-filling stage. Drought tolerance at seedling stage, determined by the traits referred to above, could therefore be an indicator of drought tolerance at the heading and grain-filling stage.

Mesic et al. (2010) analysed winter wheat yields when fertilised with 0, 100, 150, 200, 250 and 300 kg of nitrogen per ha\(^1\) in the years 1997, 2000 and 2003. Winter wheat yields in 1997 and 2000 were produced under an average rainfall and temperature regime, while 2003 was extremely dry and hot, especially during the period of winter wheat vegetation. These extreme weather conditions adversely affected winter wheat yields. Nitrogen use efficiency (NUE) had lower values for nitrogen-treated plots during the dry year 2003, compared to 1997 and 2000. The reduction in NUE increased the amount of nitrogen remaining in the soil, thus also the probability of nitrogen losses to groundwater and air. According to these results, the authors concluded that, in the case of dry years, winter wheat production cannot be maintained at a satisfactory level. NUE is also lowered, and this increases the probability of nitrogen loss to ecosystems and of negative economic results in winter wheat production.

Figure 8 presents long-term data on winter wheat yields in Croatia. These data illustrate two main trends: a decrease in the sown area of winter wheat; and a decrease in production. Although it is not possible here to analyse in detail the influence of drought on average yields of winter wheat in Croatia, it is important to stress that, relatively often, lower yields are obtained when periods of drought are recorded in the various growing phases of winter wheat.

Figure 8 – Wheat production in Croatia, 1885 to 2009.
Figure 9 shows the long-term trends in area under corn and corn for grain production in Croatia. The area sown with corn is continuously decreasing, while yields are maintained at the same average level, although with high annual variations. The lower production of corn in Croatia is very often associated with dry periods during corn vegetation, especially in the most sensitive development stages.

Figure 9 – Corn production in Croatia, 1885 to 2009
Kovacevic et al. (2009) describe how weather conditions, especially precipitation and temperature regimes, have an important role in yield formation. For example, corn yields in Croatia in the least 15-year period (1993-2007) for three less-favourable years (LFY: 2000, 2003 and 2007) were considerably lower than in three more favourable years (MFY: 1997, 2002 and 2005) (an average of 4.24 and 6.31 t/ha respectively). Drought stress and higher air temperatures are the main factors responsible for lower corn yields in LFY. For example, precipitation in the three-month period June to August (Osijek Weather Bureau) in LFY was 64 percent lower than in MFY (an average of 110 mm and 304 mm respectively). At the same time, air temperatures were 2.2°C higher (average of 22.9 and 20.7°C respectively). The alleviation of drought stress is possible by means of adequate soil management practice, especially liming. For example, by using 45 t of lime (sugar factory waste) in autumn 2000 (Sopje, Virovitica-Podravina County), a 50 percent increase in corn yield was achieved under drought stress conditions in 2003 (6.63 and 4.42 t/ha respectively). Also, by the application of 5 t/ha of hydrated calcite (73 percent CaO + 2 to 3 percent MgO + 21 percent bound water) (Podgorac, Osijek-Barannya County), corn yield under drought stress in 2007 was increased by 26 percent. The application of hydrated dolomite (47 percent CaO + 34 percent MgO) in the spring of 2005 increased corn yield in the Gradiska area (Republika Srpska, Bosnia and Herzegovina) by 43 percent.
In addition to drought, excessively moist soil conditions caused by high levels of precipitation and periods of low temperature in particular growing stages, sometimes followed by late spring or early autumn frosts, hail etc. also have a negative impact, although it is not possible to describe them in detail here. The majority of geophysicists agree that extreme weather events can be expected with greater frequency in the future. This will inevitably influence crop production in Croatia, although existing models are unable to predict such events.

Using scenarios IS92a (scenario I) and IS92e (scenario II), estimates were made of the potential change in soil water balance. Calculations were also made of the appearance of cardinal air temperatures of 5, 10, 15 and 20°C for one meteorological station in each of the lowland, mountainous and littoral regions of Croatia. An analysis of these data can highlight the various problems that will appear in particular agro-ecological regions of Croatia.

Besides changes in temperature and precipitation, a substantial change is expected in the concentration of atmospheric CO₂, which will also have a direct influence on plant production. If we assume the doubling of atmospheric CO₂ concentration, an increase in the total plant mass of different agricultural crops may be expected due to fertiliser effects. Along with increased biomass production, a corresponding increase in root organic matter can also be expected. Due to the slower decomposition of root biomass as a result of higher CO₂ concentration, the permanent enrichment of soil with organic matter can be assumed, along with an increase in humus content. However, the effects of increased CO₂ concentration on plant production will largely depend on changes in temperature and the precipitation regime.

Based on temperature and precipitation changes predicted by the climate change scenario for Croatia, using the regional model of mean global temperature in a 90 percent confidence interval (scenario I) and taking account of global changes (scenario II), the soil moisture balance for Osijek was calculated according to the Thornthwaite moisture index. Although Thornthwaite’s method for calculating evapotranspiration is indirect and includes the assumption that a maximum of 100mm of water can be stored in soil, the advantage of estimating water balance by this method is the fact that the required input parameters are temperature and precipitation. Calculations based on changes in mean monthly temperatures and overall monthly precipitation for different climate change scenarios
enable a more detailed recognition of trends, which, if the scenarios are at least partially realised, will undoubtedly have a strong influence on plant production.

Analyses of the soil water balance for lowland Croatia indicate that the temperature increase foreseen by the models will cause greater evapotranspiration. Although increased precipitation is also foreseen, it will not be sufficient to compensate for water evaporation by the combined processes of evaporation and transpiration. For this reason, the probability of dry periods in summer months will increase, which will have an adverse influence on yields.

For example, water balance for lowland Croatia allows the assumption that summer water deficiency will increase by between 30 and 60 percent (33.6 percent according to scenario I, and 59.9 percent according to scenario II) by the year 2100. Based on these scenarios, the number of days with cardinal temperatures above 5, 10, 15 and 20°C was calculated in order to analyse the expected changes in plant production resulting from climate change.

According to the results, the annual number of days with a temperature above 5°C will be higher in 2100 than in 2011 by between 35 and 84 days in lowland Croatia. A cardinal temperature of 10°C will last 25 to 41 days longer than in 2011, and a temperature of 15°C will last 26 to 46 days longer. The period with a temperature above 20°C will also be prolonged, depending on the scenario, by between 45 and 73 days.

According to these estimates, it can be assumed that the sowing of spring crops will commence at an earlier date and, depending on the possibility of providing sufficient irrigation water, the growing period will last longer. Yields will be constrained by the length of the growing period, the provision of sufficient water for intensified evapotranspiration, and possible crop damage due to early spring frosts and excessively high temperatures in summer. Winter crops will have more favourable conditions for growth and development, thus some increases in yield can be expected. In such conditions, however, considerable problems may occur in terms of weed, disease and pest control.

Spring crops will suffer from water deficiency in the summer months and, without the provision of sufficient water for irrigation, in some years yields might be substantially reduced due to droughts. Besides irrigation, the adverse effects of water deficiency can also
be avoided by the application of adequate tillage systems for a given region, and by the choice of appropriate sowing dates and seed.

In mountainous regions, where there is sufficient water according to current average water balance values, average water deficiency can be expected in August. Depending on the scenario, it will range between 13.6 and 27.6 mm in the given example. Based on the duration of particular cardinal temperatures, the prolongation of the growing period by between 25 and 45 days can be assumed, which might have a positive impact on yields of field crops. Higher air temperatures result in earlier emergence and the more rapid achievement of particular growth phases. Compared to the current situation, the ripening and harvesting of most annual crops will be brought forward by at least 15 to 25 days. On the other hand, faster initial growth in spring increases the risk of crop damage by frost. The expected temperature increase should provide sufficient warmth for thermophilic crops.

Evapotranspiration foreseen for Zadar according to the presented scenarios allows for an estimation of changes in the coastal region and on the islands, where substantial water deficiency is expected during the summer months. According to the calculation for Zadar, an increase in water deficiency in the soil of 25.5 percent is foreseen by scenario I, and of 56.5 percent by scenario II. The duration of a cardinal temperature of 10°C will be prolonged from 55 (scenario I) to 90 (scenario II) days by the year 2100. According to the scenario II, temperatures above 10°C would last practically throughout the year. If sufficient water cannot be provided, some drought-associated problems may be solved by shifting sowing times to periods with sufficient precipitation. The effects of extremely high temperatures on some plants should also be taken into account.

According to agro-climatic indicators estimated on the basis of the temperature increase assumed by the two scenarios, in the absence of significantly higher levels of precipitation and with the expected increase in evapotranspiration, the majority of the lowland and coastal areas of Croatia will be exposed to the risk of drought. This is also the case for summer months in mountainous regions, particularly with respect to the water-retention potential of karst soils. The expected increase in precipitation may only partially compensate the impact of intensified evapotranspiration due to higher temperatures. The provision of sufficient water, or the favourable distribution of precipitation, may have a positive impact on yields of agricultural crops in the event of higher temperatures.
4. Recommendations for decision makers based on the research findings

The impact of climate change on agricultural production in Croatia requires long-term adaptation programmes that enable the efficient adjustment of agriculture to changes in agro-ecosystems.

1. There will be a need for new practices and new soil tillage methods that are adapted to the changed climate conditions. These include conservation tillage, no tillage and so-called adaptable soil tillage.
2. New varieties and hybrids suitable for intensive production under abiotic stress conditions will need to be developed.
3. Increased flexibility will be required in crop rotation, with the introduction of new crops and different hybrids or varieties of the same crop in particular production areas.
4. Effective plant protection measures will be needed to combat weeds, pests and plant diseases.
5. Fertilisation and the application of soil improvers will have a very important role in future agricultural production under changed climatic conditions.
6. The importance of drainage and irrigation will increase.
7. The timing of sowing and harvesting will change in different parts of Croatia, based on cardinal temperatures.
8. New areas will became favourable for specific types of agricultural production, and at the same time some existing agricultural regions in Croatia will be reduced or lost, primarily because of a shortage of water for irrigation.

In order to achieve better adaptation it will be necessary to introduce new research programmes. The application of research results may lead to cost reductions and allow a satisfactory level of agricultural production to be maintained. In order to achieve this, a multidisciplinary approach must be applied to solving the problems faced by the agricultural sector under changed climatic conditions.
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The Impact of Climate Change on Food Production in the former Yugoslav Republic of Macedonia

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1. Country overview
Climate change is taking place in the former Yugoslav Republic of Macedonia. Recent heat waves and relative snowfall in the last few winters are “windows” on how the climate might look in the future. Studies of the impacts of these phenomena indicate major changes in agricultural production. Most evidence points to the likelihood of an acceleration in the pace of change in the future. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) indicates that changes in Europe, based on global circulation models (GCM), are most significant in the Mediterranean and Continental climate zones, and the former Yugoslav Republic of Macedonia is located at the meeting point of the two.

1.1 Geography
The former Yugoslav Republic of Macedonia is situated in southern Europe, at the centre of the Balkan Peninsula. Its total surface area is 25,713 km$^2$, of which 79 percent comprises hills and mountainous terrain, 19.1 percent plains, and about 1.9 percent water bodies. As a central Balkan state, bordered by countries that vary in terms of economic potential and development, the country’s geographical position is significant. The neighbouring countries are directed towards each other in terms of trade; their economies are complementary; and the region’s main transportation routes pass through the country’s territory.

In hydrographical terms, the country is a unique natural basin in the Balkan Peninsula and the wider area, due to the fact that 84 percent of the available water is from domestic resources, while only 16 percent is external waters. There are four river basins (Vardar, Crn Drim, Strumica and Juzna Morava); three major natural lakes (Ohrid, Prespa and Dojran); and 4,414 springs. With annual per capita water resources of around 3,150m$^3$, the country falls into the middle category of European countries in terms of available water resources. This figure is close to the limit threshold of water resources needed for sustainable development.

Areas at an elevation of between 500 and 1,000 m predominate (44.01 percent). Forests cover around 30 percent of the territory of the country (947,653 ha.). The total cultivable agricultural land in 2005 was 546,000 ha, of which 82 percent was arable land and gardens. Pastureland covers 682,000 ha. Agriculture is one of the most important sectors in the Macedonian economy due to its importance in terms of social security and poverty reduction. It provides a livelihood for the absolute majority of the population and accounted for 14 percent of GDP in 2006. Rural economies that are based on agriculture and natural resources are particularly vulnerable to various anthropogenic stressors, including climatic hazards, variability and long-term climate change.

1.2 Climate
In spite of its relatively small area, the country has a diverse climate, with the following relatively homogeneous regions and sub-regions:

- Sub-Mediterranean climate (50 to 500 m)
- Moderate/continental/sub-Mediterranean climate (up to 600 m)
- Hot continental climate (600 to 900 m)
- Cold continental climate (900 to 1,100 m)
- Sub-forest/continental/mountainous climate (1,100 to 1,300 m)
- Forest/continental/mountainous climate (1,300 to 1,650 m)
- Sub-alpine mountainous climate (1,650 to 2,250 m)
- Alpine mountainous climate (higher than 2,250 m)
1.3 Climate variability findings up to 2006

Analysis of climate variability is currently carried out by the Hydrometeorological Service (HMS) and comprises three separate aspects: an analysis of climate parameters in the period 1971 to 2000 for 34 meteorological stations; an analysis and comparison of climate data series for the periods 1961 to 1990 and 1971 to 2000 for the main meteorological stations; and an analysis and interpretation of climate variations during the 20th century for five meteorological stations with the longest data series.

Climate parameters such as air temperature, precipitation, snow and snow cover, wind, insolation, cloudiness and fog are monitored in order to define the country’s climate characteristics and to analyse climate data on the country. Existing data from the period 1971 to 2000 are analysed for 34 meteorological stations in order to define the climate of a specific area and to describe the characteristics of the spatial distribution of the meteorological-climatological elements and phenomena. The aim of such analyses is to use existing data towards defining climatic types and sub-types on the territory of the country.

Variations and standard statistical parameters for the main climate elements (temperature and precipitation) are analysed for the main meteorological stations only — that is, Gevgelija, Demir Kapija, Strumica, Skopje Petrovec, Stip, Bitola, Prilep, Kriva Palanka, Ohrid, Berovo, Krusevo, Mavrovo, Lazaropolje and Popova Sapka. Climate data registered at these meteorological stations cover the entire territory of the country and all characteristic climatic areas. Climate variability is analysed on the basis of a comparison of the data of two series with a duration of 30 years. Differences in mean annual values for air temperature and precipitation, as well as differences in mean air temperature for the coldest and hottest month during the year are analysed for the period 1971 to 2000, in comparison with the period 1961 to 1990. In terms of air temperature, it can be concluded that the period 1971 to 2000, at annual level, was warmer than the period 1961 to 1990,
while respective mean monthly temperatures show differences from year to year. Differences in average annual air temperatures for the two 30-year periods vary from -0.1°C to 0.2°C. Winters and summers during the last 30-year period are warmer compared to the previous period. For example, differences in mean monthly air temperature for winter months (January and February) range from 0.5°C to 0.8°C, and for summer months (June, July and August) from 0.1°C to 0.8°C. In spite of this, autumn and spring months are colder than in the previous 30-year period. The highest values of the mean annual deviations in air temperature in the country are registered for regions with a sub-Mediterranean climate (Valandovo 0.7°C, Gevgelija 0.5°C and Nov Dojran 0.2°C).

A comparison of the two series of precipitation data shows a decrease in the annual amount of precipitation in the period 1971 to 2000 compared to the annual amount of precipitation for 1961 to 1990 for all meteorological stations in the country. The decrease in precipitation at annual level is most pronounced at the Mavrovi Anovi (up to -96.6 mm) and Popova Sapka (up to -108.0 mm) meteorological stations — that is, in regions with sub-alpine mountainous and alpine mountainous climate. Also, large negative differences in precipitation amounts at annual level were recorded at the Prilep (-35.0 mm), Gevgelija (-32.4 mm), Ohrid (-36.0 mm) and Lazaropole (-38.5 mm) meteorological stations. The difference in the annual amount of precipitation for the Bitola and Krusevo meteorological stations in the two periods has a positive value (9.1 mm and 6.7 mm respectively). A decrease in precipitation was recorded during January, March, May, June, November and December.

The third aspect of the analysis was a comparison of the 80-year data series for five meteorological stations: Bitola, Skopje, Stip, Prilep and Demir Kapija. Variations in the main climate parameters (air temperature and precipitation) in the 20th century were investigated for these stations, since they have the longest data series (from 1926 to 2005).

The variations in air temperature are presented in Figure 1. During the 1950s, higher air temperatures were recorded at all the meteorological stations. These hot years were followed by a colder period, from 1961 to 1998. Following this period, and after 1996 in particular, average annual temperatures increased and are continuously higher than the long-term average. The hottest year recorded on Macedonian territory was 1994, which was warmer than the multi-annual average by 2.0°C in Skopje, 1.8°C in Demir Kapija, and 1.6°C in Bitola. Significantly higher average annual temperatures were recorded in 1999, 2002 and 2003.

Summer air temperatures show significantly higher values in the period from 1990 to 2005, especially in 1993, 1994, 2000, 2001, 2003 and 2005. The absolute maximum annual air temperature was recorded in July 2000 in Demir Kapija (44.8°C), Gevgelija (44.6°C) and Stip (43.2°C); and in August 1994 in Skopje Petrovec (43.2°C). In 2007, extremely high air temperatures were also recorded on July 24 at the main meteorological stations: 45.7°C in Demir Kapija, 45.3°C in Gevgelija, 43.5°C in Stip, 42.9°C in Skopje Petrovec, 39.0°C in Berovo, 40.2°C in Kriva Palanka, 41.3°C in Prilep, 34.0°C in Mavrovi Anovi, 33.1°C in Lazaropole, 43.0°C in Strumica, 37.5°C in Ohrid and 43.4°C in Skopje-Z. Rid. These temperatures exceed the multi-annual absolute maximum air temperature ever recorded.
Figure 13 Average annual temperatures and linear trends for the period 1926 to 2005 for Skopje and Bitola meteorological stations

The annual amounts of precipitation presented in Figure 2 show a linear decreasing trend for all meteorological stations. A decrease in precipitation at annual level during the last 20 years in comparison with the period 1961 to 1990 is recorded especially in 1988-1990, 1992-1994, 2000 and 2001. A decrease in precipitation occurred in recent years in May, especially from 1985. Amounts of precipitation in November are decreasing for Stip, Bitola, Demir Kapija and Ohrid stations.

Figure 14 Annual amounts of precipitation and linear trends for the period 1926 to 2005 for Skopje and Bitola meteorological stations

Regarding insolation, the highest annual value (about 2,400 sunny hours) appears in regions with a sub-Mediterranean climate, while in regions with an alpine and sub-alpine mountainous climate the annual number of sunny hours is around 2,200. A comparison of the two data series (1971-2000 and 1961-1990) shows an increase in the annual value for insolation in regions with a sub-Mediterranean and moderate continental sub-Mediterranean climate, and also in the region with an alpine mountainous climate.
Based on 30-year observations, statistical parameters were calculated for cloudiness at meteorological stations and systematised into average monthly and annual values, which show that average annual cloudiness varied between 3.8 tenths in Strumica and 5.3 tenths in Kriva Palanka. The highest value for cloudiness is recorded in western areas of the country in winter, and the lowest amount of cloudiness was monitored in the regions with a sub-Mediterranean climate.
The data in the maps clearly show a rise in temperature during the growing period in the most important agricultural regions in the country, including Pelagonija, Polog, the Skopje-Kumanovo valley, the Bregalnica River valley, Ovče Pole, Strumica, Tikves, Veles and Gevgelija Valandovo. Higher temperatures cannot usually be related to negative effects on agricultural production. The effects of higher temperatures depend on many other environmental conditions, such as previous temperature, rainfall, evapotranspiration and drought. In the case of the former Yugoslav Republic of Macedonia, the rise in temperature cannot be said to be negative. However, further analysis is likely to show that higher temperatures will affect agricultural production in some regions due to increased aridity.

1.4 The national greenhouse gas inventory

The national greenhouse gas (GHG) inventory was prepared for the years 1999 to 2002 (with 2000 as the base year) and covers the following sectors: energy, industrial processes, agriculture, land-use change and forestry, waste and, for the first time, the use of solvents and other products. Six GHGs covered by the United Nations Framework Convention on Climate Change (UNFCCC) were considered: CO$_2$, CH$_4$, N$_2$O, HFCs, PFCs, and SF$_6$. In addition, information is provided on indirect GHGs: CO, NOx, SOx, and NMVOCs.

Total CO$_2$-eq emissions in the country for the period 1990 to 2002 ranged from 11.9 to 14.4 million tons. Emissions for the base year 2000 amounted to 14.318 kt CO$_2$-eq, that is, 7.16 tons CO$_2$-eq per capita. The main contributor to total CO$_2$-eq emissions was the energy sector, with about 70 percent of total emissions. The second biggest contribution came from the agricultural sector, at between 10 and 15 percent, while all other sectors contributed less than 10 percent each. An exception was 2000, when, due to massive forest fires, emissions from the land-use change and forestry (LUCF) sector represented about 14 percent of total national emissions. Between 75 and 80 percent of equivalent emissions were direct CO$_2$ emissions from burning; between 12 and 14 percent were CH$_4$ emissions; between 5 and 9 percent were N$_2$O emissions; and about 2 percent were CO emissions. It is clear that the main sources of emissions were agricultural soils and enteric fermentation, which each represent between 40 and 50 percent of the total CO$_2$-eq emissions, while manure management and flooded rice fields account for a smaller share.

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</tr>
</thead>
<tbody>
<tr>
<td>Enteric fermentation</td>
<td>694.26</td>
<td>684.18</td>
<td>697.62</td>
<td>703.08</td>
<td>704.97</td>
<td>692.16</td>
<td>659.4</td>
<td>634.62</td>
<td>567.84</td>
<td>570.36</td>
<td>551.04</td>
<td>560.28</td>
<td>542.9</td>
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<td>Manure management</td>
<td>168.46</td>
<td>166.99</td>
<td>164.52</td>
<td>162.26</td>
<td>166.87</td>
<td>167.67</td>
<td>172.19</td>
<td>170.72</td>
<td>162.63</td>
<td>165.36</td>
<td>163.05</td>
<td>158.48</td>
<td>151.12</td>
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<tr>
<td>Rice fields</td>
<td>9.24</td>
<td>9.03</td>
<td>9.03</td>
<td>5.46</td>
<td>1.89</td>
<td>1.25</td>
<td>4.41</td>
<td>5.46</td>
<td>4.62</td>
<td>4.41</td>
<td>3.99</td>
<td>1.68</td>
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<tr>
<td>Agricultural soils</td>
<td>1,035.4</td>
<td>1,007.5</td>
<td>1,010.6</td>
<td>985.8</td>
<td>964.1</td>
<td>964.1</td>
<td>846.3</td>
<td>759.5</td>
<td>728.5</td>
<td>536.3</td>
<td>654.1</td>
<td>368.9</td>
<td>362.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,907.36</strong></td>
<td><strong>1,867.7</strong></td>
<td><strong>1,881.56</strong></td>
<td><strong>1,932.62</strong></td>
<td><strong>1,887.97</strong></td>
<td><strong>1,825.14</strong></td>
<td><strong>1,593.5</strong></td>
<td><strong>1,570.3</strong></td>
<td><strong>1,463.59</strong></td>
<td><strong>1,276.43</strong></td>
<td><strong>1,380.58</strong></td>
<td><strong>1,312.54</strong></td>
<td><strong>1,077</strong></td>
</tr>
</tbody>
</table>

Source: Second National Communication on Climate Change, the former Yugoslav Republic of Macedonia, 2008
2. The agricultural sector in the former Yugoslav Republic of Macedonia

2.1 Introduction

Agriculture (including hunting, forestry and fishing) is the third largest sector in terms of contribution to GDP, after the services and production industries. The contribution of agriculture and the processing industry was approximately 16 percent, while the agricultural sector accounted for 9.7 percent of GDP in 2009. According to the latest census (2002), approximately 43 percent of the population and 36 percent of the work force were involved in agriculture. The number of family agricultural holdings was estimated at 192,675 and the average size of the farms in private ownership was between 2.5 and 2.8 ha. In 2009, livestock production contributed 30.9 percent of the total value of national agricultural production. Out of total livestock production, milk contributed 57 percent, followed by pork (13.9 percent), beef (11.8 percent) and others (sheep and goats: 6 percent).

Agricultural land in the former Yugoslav Republic of Macedonia covers 1.014 million ha, of which 500,000 ha is arable land and the remainder (51 percent) pastureland. In 2009, out of the total cultivated land, 420,000 ha were arable fields and gardens; 14,000 ha orchards; 21,000 ha vineyards; and 58,000 ha meadows. Cultivated land decreased from 633,000 ha in 1999 to 513,000 ha in 2009, mainly due to land abandonment (migration of the rural population to urban areas) and urban/industrial development, which took place at the expense of potentially productive agricultural land.

2.2 Crop production

Crop production data can be divided into six main categories, and in 2009 the production of cereals, at 179,421 ha, was the largest of them. Among industrial crops, tobacco remained dominant as a very important labour-intensive crop in areas with difficult agricultural production conditions. Forage crops were grown in livestock areas, while horticultural crops dominated areas in the south of the country with a Mediterranean climate. Fruit crops were mostly grown in the western parts of the country, where climate conditions are more humid and where rainfall is heavier. Viticulture was predominant in the central part of the country due to the favourable soil conditions with high temperatures and low humidity.

**Cereals**

Cereals were the most important crop group: in 2009 they covered 37 percent of the total arable agricultural area. The predominant cereal is wheat, followed by barley and maize, with small areas of rye and rice.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (ha)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>88,256</td>
<td>271,117</td>
</tr>
<tr>
<td>Barley</td>
<td>48,756</td>
<td>146,372</td>
</tr>
<tr>
<td>Rye</td>
<td>3,777</td>
<td>9,089</td>
</tr>
<tr>
<td>Oats</td>
<td>2,770</td>
<td>4,960</td>
</tr>
<tr>
<td>Maize</td>
<td>32,737</td>
<td>154,237</td>
</tr>
<tr>
<td>Unmilled rice</td>
<td>3,125</td>
<td>19,870</td>
</tr>
</tbody>
</table>

Source: MAFWE 2010

**Industrial crops**

Out of the total area of industrial crops in 2009, tobacco represented 79 percent, sunflowers 18.3 percent, and poppies just 2.7 percent. Tobacco production is based on the cultivation of oriental aromatic tobacco. Tobacco is the country’s most important agricultural export product, and approximately 37,000 households are engaged in tobacco production.
Sunflowers are cultivated mainly in the Pelagonija region (50 to 70 percent), followed by Kumanovo and Ovche Pole. In 2009, sunflower crop area decreased by 15.8 percent compared to 2008, while the yield per hectare increased by 44 percent.

### Table 3. Area and production of industrial crops in 2009

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (ha)</th>
<th>Production (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobacco</td>
<td>17,810</td>
<td>24,100</td>
</tr>
<tr>
<td>Sunflower</td>
<td>4,210</td>
<td>7,800</td>
</tr>
<tr>
<td>Poppy</td>
<td>620</td>
<td>500</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Water Economy, 2010

**Fodder crops**

The production of fodder and forage crops meets only 30 to 35 percent of total national needs. The deficit is one of the main factors limiting the development of the cattle industry. In 2009, forage and fodder crops covered only 2.9 percent (29,680 ha) of the total arable area.

**Vegetables**

Vegetables are grown mostly in the southern parts of the country that have a Mediterranean climate, as well as in the eastern and northern parts that have a favourable mild continental climate. The total harvested area was approximately 59,319 ha in 2009, which is a slight increase from 2008. Vegetables are also grown in protected production systems (glass or plastic greenhouses) on a total area of around 5,000 ha (260 ha under glass and 4,740 ha under plastic). In 2009, the area under protection increased by about 19.2 percent compared with the average for the period 2005 to 2008. The production of vegetable crops in 2009 rose by approximately 20 percent compared to 2008.

**Orchards**

Orchards cover about 1.4 percent of agricultural land, or approximately 14,000 ha. The predominant fruit crop is apples (at about 52 percent), followed by plums (17 percent), sour cherries (13 percent), pears (5 percent) and others (apricots, peaches, almonds, walnuts etc.) on the remaining 13 percent. Total annual production is approximately 106,000 tons, the majority of which was exported in 2009.

**Viticulture**

All aspects of viticulture contribute between 17 and 20 percent of agricultural GDP. Following tobacco, grapes are the second most important crop in terms of export value. The country can be divided into three vine-growing regions: Vardar (i.e. Povardarie); Pelagonija-Polog (western) and Pchinja-Osogovo (eastern). Wine grapes cover 70 percent of the total area (40 percent white varieties and 60 percent red varieties). Around 25,000 farms grow grapes, of which 70 percent are individual holdings and 30 percent agricultural companies. Average yields were approximately 10.11 tons/ha in 2009.

### 3. Summary of findings and results from climate change scenarios up to 2100

To obtain information on current and future large-scale climate variability, the results of four GCMs (general circulation models) are used together with the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis (Kalnay et al., 1996; Kistler et al., 2001) to describe the relationship between large-scale climate variability across South Eastern Europe and local climate variability in the former Yugoslav Republic of Macedonia. The four GCMs used in the analysis are the Australian coupled GCM CSIRO/Mk2; the UK coupled GCM UKMO/HadCM3; the USA coupled GCM DOE-NCAR/PCM; and the German coupled GCM MPI-DMI/ECHAM4-OPYC3. These differ from the GCMs used in the former Yugoslav Republic of Macedonia’s Initial National Communication. As simulations of future climate using GCMs are based on a limited number of emission scenarios, usually SRES A2 and B2, local climate change projections were

For Macedonian climate change projections, direct GCM output and empirical downscaling, both in combination with pattern scaling, have been used. Empirical models were developed separately for each season.

On the basis of this methodology, projections of the main climate parameters (temperature and precipitation) were made for the 21st century. Climate change is estimated for the periods 1996 to 2025 (labelled 2025), 2021 to 2050 (labelled 2050), 1946 to 2075 (labelled 2075), and 2071 to 2100 (labelled 2100), in comparison with the reference period 1961 to 1990 (labelled 1990), separately for six different climatic regions and sub-regions in the country on the basis of empirical downscaling, and for the country as a whole on the basis of direct GCM output. As none of the SRES emission scenarios is considered more probable than the others, the values are presented as mean values across all six marker scenarios (labelled mean), as well as their range across the six emission scenarios using averages across the GCMs (labelled low/high).

According to estimated changes in average daily air temperature and precipitation for the entire country, based on direct GCM output, the average increase in temperature compared to the reference period is between 2.9°C in 2075 and 3.8°C in 2100. The average amount of precipitation is expected to decrease from -8 percent in 2075 to -13 percent in 2100 compared to the reference period.

The results show the highest increase in air temperature by the end of the 21st century. Tables 4 and 5 show the highest increase in air temperature in summer together with the most intensive decrease in precipitation. In the case of precipitation, practically no change is expected in winter, but a decrease is expected in all other seasons. An increase in average daily temperature range is expected for summer and a small decrease in winter.

Table 4. Projected changes in average daily air temperature (°C) separately for each season for the former Yugoslav Republic of Macedonia based on direct GCM output

<table>
<thead>
<tr>
<th>Average temperature (°C)</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2025</td>
<td>2050</td>
<td>2075</td>
<td>2100</td>
</tr>
<tr>
<td>Low</td>
<td>0.7</td>
<td>1.4</td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Mean</td>
<td>0.8</td>
<td>1.7</td>
<td>2.3</td>
<td>3.0</td>
</tr>
<tr>
<td>High</td>
<td>0.9</td>
<td>1.9</td>
<td>2.9</td>
<td>4.2</td>
</tr>
<tr>
<td>2025</td>
<td>0.8</td>
<td>1.5</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>2050</td>
<td>0.9</td>
<td>1.7</td>
<td>2.8</td>
<td>3.7</td>
</tr>
<tr>
<td>2075</td>
<td>1.1</td>
<td>2.0</td>
<td>3.6</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Table 5. Projected changes in precipitation (%) separately for each season for the former Yugoslav Republic of Macedonia based on direct GCM output

<table>
<thead>
<tr>
<th>Precipitation (%)</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2025</td>
<td>2050</td>
<td>2075</td>
<td>2100</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>-1</td>
</tr>
<tr>
<td>High</td>
<td>-2</td>
<td>-1</td>
<td>1</td>
<td>-3</td>
</tr>
<tr>
<td></td>
<td>-3</td>
<td>-7</td>
<td>-17</td>
<td>-23</td>
</tr>
</tbody>
</table>

Additional projections were made of changes in scalar wind speed and incident solar radiation. For both variables, the relative expected changes are very small, not exceeding 10 percent in either direction. A minor increase in solar radiation is expected in all seasons, the highest increase being in the summer. This corresponds with projected precipitation changes, which also show the biggest decrease in summer. Practically no change is expected in wind speed over the country when considering the direct output of the four GCMs.

Local responses to large-scale climate variability across the country differ in the different parts of the country. In the expectation that climate change will affect these regions in different ways, empirical downscaling was carried out for several locations that represent different climatic sub-regions of the country. A comparison of the empirical downscaling results and the direct GCM output shows that local
projections indicate a more significant increase in air temperature in winter and spring compared to direct GCM output for the country. In addition, local projections show a less drastic decrease in precipitation in the summer period. Projections of change in mean daily air temperature and daily amounts of precipitation for other seasons are comparable for both methods.

Local projections were made of average daily air temperature (°C) and precipitation (%) for different seasons, and at annual level, for different sub-regions of the country. The values are based on projections of results from four GCMs scaled to six emission scenarios (SRES A1T, A1Fl, A1B, A2, B1 and B2).

In the south east of the country, with a prevailing sub-Mediterranean climate (represented by Gevgelija and Nov Dojran meteorological stations) a very slight decrease in precipitation is expected until the end of the 21st century in winter. A more intense decrease in precipitation is expected in all other seasons, reaching a value of -19 percent in summer. Taking into consideration the changes in temperature, local projections show the highest increase in air temperature of 6°C in summer. The difference between the winter and summer increase in air temperature is particularly noticeable in this region. The central region, which faces a combination of continental and sub-Mediterranean climate impacts (represented by Veles, Skopje-Petrovec, Strumica and Stip stations), shows a more intensive temperature change in winter and a less intensive change in summer and autumn compared to the south eastern region. The highest increase in air temperature (of 5.4°C) is expected in summer. Practically no change in precipitation is expected in winter, and a decrease in precipitation is expected in all other seasons, reaching a maximal value of -23 percent in summer.

**Table 6. Projected changes in average daily air temperature (°C) and precipitation (%) for the central region of the former Yugoslav Republic of Macedonia under a combination of sub-Mediterranean and continental climate impacts (represented by Veles, Strumica, Skopje-Petrovec and Stip meteorological stations)**

<table>
<thead>
<tr>
<th>Average temperature (°C)</th>
<th>Precipitation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>2025</td>
</tr>
<tr>
<td>Low</td>
<td>-1</td>
</tr>
<tr>
<td>Mean</td>
<td>-3</td>
</tr>
<tr>
<td>High</td>
<td>-6</td>
</tr>
</tbody>
</table>

**Table 7. Projected changes in average daily air temperature (°C) and precipitation (%) for the south eastern part of the former Yugoslav Republic of Macedonia under sub-Mediterranean and continental climate impacts (represented by Gevgelija and Nov Dojran meteorological stations).**

<table>
<thead>
<tr>
<th>Average temperature (°C)</th>
<th>Precipitation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>2025</td>
</tr>
<tr>
<td>Low</td>
<td>-1</td>
</tr>
<tr>
<td>Mean</td>
<td>-3</td>
</tr>
<tr>
<td>High</td>
<td>-5</td>
</tr>
</tbody>
</table>

For the southern and south western parts of the country (represented by Bitola and Prilep meteorological stations and Ohrid and Resen meteorological stations respectively), where there is a prevailing continental climate, the climate change projections are quite different even though they are geographically close. In the southern region, projected changes in precipitation are very similar to those regions with prevailing sub-Mediterranean climate impacts. Almost no change in precipitation is expected in winter and a decrease is expected in other seasons, reaching a maximal value of -22 percent in summer. A slightly more significant increase in temperature is expected for this region compared to regions with sub-Mediterranean climate impacts. The difference is particularly evident in projections for the winter period, when an increase of 5.3°C is expected. The biggest increase in air temperature (5.4°C) is expected in summer. Projected changes in temperature for the south western region are far lower than for the
southern region. A slight increase in precipitation (of 5 percent) is expected in winter, but a clear decrease is expected in other seasons.

In the eastern part of the country, with prevailing continental climate impacts (represented by Berovo and Kriva Palanka meteorological stations), a slight increase in precipitation of 6 percent is expected in winter, and a decrease in all other seasons, the most intensive decrease (~20 percent) being in the summer. In summer and autumn, a rise in daily air temperature is expected, reaching a maximal value of 5.2°C in summer.

For all three climate sub-types found in the north western part of the country under prevailing alpine climate impacts (represented by Lazaropole, Popova Sapka and Solunska Glava meteorological stations), the projected changes in air temperature and precipitation are very similar. An increase of precipitation of 5 percent until the end of the 21st century is expected in winter, with a more intense decrease in all other seasons. The most intensive decrease in precipitation (18 percent) is expected in summer. The expected change in air temperature is most significant in this region of the country. The biggest increase in air temperature (5.9°C) is expected in summer, although the difference between seasons is not large.

Table 8. Projected changes in average daily air temperature (°C) and precipitation (%) for the north western part of the former Yugoslav Republic of Macedonia under prevailing alpine climate impacts (represented by Lazaropole, Popova Sapka and Solunska Glava meteorological stations)

<table>
<thead>
<tr>
<th></th>
<th>Average temperature (°C)</th>
<th>Precipitation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2025</td>
<td>2050</td>
</tr>
<tr>
<td>Low</td>
<td>1.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Mean</td>
<td>1.3</td>
<td>2.6</td>
</tr>
<tr>
<td>High</td>
<td>1.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Although empirical downscaling projections of climate change at local level represent a step towards obtaining the required knowledge of how different sub-regions of the country might respond to large-scale climate change, the uncertainties related to the results should be taken into consideration. This means that projections of the future climate should not be regarded as exact predictions but as indicators of the direction in which climate change might develop.

4. Summary of the analysis of vulnerability and adaptation assessment in agriculture

4.1 Crop production

4.1.1 Changes in the climatic and agro-climatic environment

Agro-climatic conditions were analysed in order to determine which areas of the country are the most vulnerable to climate change in terms of crop production. The analysis was carried out using models developed in the geographic information systems (GIS) environment. This was the first time such analysis had been carried out in the country, and through a series of raster maps a clear picture of the vulnerable areas was derived. Climatic and agro-climatic conditions in the country were analysed based on a comparison of two series of meteorological data (1961 to 1990 and 1971 to 2000). A model for water deficit for agricultural crops was developed for the periods 1961 to 1990 (map 1) and 1971 to 2000 (map 2). In both periods, a bigger water deficit appears in the central part of the country (the central Vardar River valley and its confluence with the rivers Crna and Bregalnica). In the second period (map 2) this
area is bigger and at the same time the deficit is bigger. The new area, with such a high water deficit, appears in the most southern part of the Vardar River valley (map 2). Map 3 shows a difference compared to maps 1 and 2: it indicates an increasing water deficit for normal crop growing in most of the country’s agricultural areas (the whole of the Vardar River valley, Strumica River valley, Ovche Pole, Skopje and Kumanovo regions, Pelagonija valley, Polog valley etc.). A similar situation can be seen on map 4 (showing the difference between the drought index by De Martonne for the periods 1961 to 1990 and 1971 to 2000). This map shows the areas of the country in which there is an increase in aridity. This analysis proves that agro-climatic conditions for crop growing in the country are becoming more severe for most agricultural areas and that if adaptation measures are not implemented in the agricultural sector, crop production in particular will decrease due to increased aridity and a bigger water deficit.

4.1.2 Vulnerability assessment for the crop sector

The maps above clearly show that most of the country’s important agricultural areas are vulnerable to climate change. The data have been used to identify several vulnerable zones in the former Yugoslav Republic of Macedonia.

1. The most vulnerable zone is Povardarie region, especially the confluence of the rivers Crna and Bregálnica with the Vardar (Kavadarci).
2. Very vulnerable zones are:
   - the south eastern part of the country (Strumica);
   - the southern Vardar valley (Gevgelija);
   - Skopje-Kumanovo valley (Skopje); and
   - Ovche Pole (Stip).

3. Less vulnerable zones are:
   - Pelagonija valley (Bitola);
   - Polog (Tetovo and Gostivar - no climate predictions); and
   - the Prespa/Ohrid region (Resen).

The meteorological stations indicated in brackets are the most suitable for evaluating vulnerability in the regions covered in the country’s Report on Climate Change Scenarios.

The most vulnerable crops were defined according to cropping patterns in vulnerable areas. The predominant crops in vulnerable regions were determined as vulnerable crops:
1. vine grapes, as the most important crop in Povardarie region;
2. tomatoes, as the most important vegetable crop in the predominantly vegetable-growing agriculture in the south eastern part of the country (Gevgelija-Strumica);
3. winter wheat, as the most important cereal in Skopje-Kumanovo and Ovche Pole;
4. apples in the Prespa/Ohrid region, especially Resen; and
5. alfalfa, as a crop with a very high water demand and huge importance in the livestock sector, which is vulnerable in all agricultural regions in the country, especially the Bitola area.

Expected decreases in yield were calculated using the Food and Agriculture Organization (FAO) Crop Yield Response to Water Deficit methodology. This methodology compares the ratio of actual yield (Ya) and maximal yield (Ym) with the ratio of actual evapotranspiration (ETa) and maximal evapotranspiration (ETm). Each crop has a different sensitivity to water deficit, thus the crop response factor (ky) is factored into the calculation (as recommended by FAO). Calculations were made using the downscaled climate change scenario prepared for the second national communication to the UNFCCC. The data are presented in Table 9.

<table>
<thead>
<tr>
<th>Area</th>
<th>Crop</th>
<th>2025</th>
<th>2050</th>
<th>2075</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kavadarci</td>
<td>Grapes</td>
<td>46</td>
<td>50</td>
<td>55</td>
<td>59</td>
</tr>
<tr>
<td>Gevgelija</td>
<td>Tomato</td>
<td>75</td>
<td>78</td>
<td>81</td>
<td>84</td>
</tr>
<tr>
<td>Strumica</td>
<td>Tomato</td>
<td>72</td>
<td>75</td>
<td>79</td>
<td>82</td>
</tr>
<tr>
<td>Stip</td>
<td>Winter wheat</td>
<td>14</td>
<td>17</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>Skopje</td>
<td>Winter wheat</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>Bitola</td>
<td>Alfalfa</td>
<td>58</td>
<td>62</td>
<td>66</td>
<td>70</td>
</tr>
<tr>
<td>Resen</td>
<td>Apple</td>
<td>46</td>
<td>50</td>
<td>55</td>
<td>59</td>
</tr>
</tbody>
</table>

The results for decrease in yield are dramatic, but even now most of these crops are irrigated, since planting without irrigation is not reasonable. The assumption is that crops will be planted without irrigation, which explains the large decrease.

4.1.3 Adaptation measures for the crop production sector

Adaptation techniques for crop production in the country can be divided between irrigated agriculture and rain-fed agriculture.

4.1.3.1 Adaptation measures in irrigated agriculture
Although more than 120,000 ha of Macedonian agricultural land can be irrigated, during the last few years around 30,000 ha were irrigated. This situation is unfavourable, especially in terms of adaptation to climate change, since irrigation is the best available practice for Macedonian agriculture. The best adaptation strategy for irrigated areas would be the spread of water-saving techniques in order to maintain the same amount of water in the same, or even bigger, irrigated areas. The best available practice is increased irrigation efficiency through micro-irrigation (90 percent water-use efficiency, compared to less than 50 percent in furrow irrigation and about 70 percent in sprinkler irrigation). In addition to the technical rehabilitation of irrigation schemes, several important measures remain to be undertaken in the coming period. The first step is to determine the real price of irrigation water, which farmers should have to pay in order for them to recognise the importance of water-saving techniques. Structural changes in water management and greater know-how among all players in the sector are also necessary.

### 4.1.3.2 Adaptation measures in rain-fed agriculture

There is little opportunity to apply the best available adaptation technology — irrigation — in areas without irrigation schemes, infrastructure etc. Adaptation technologies should thus be oriented towards the mitigation of the negative effects of drought and stress on crop development and yield.

Adaptation measures for rain-fed agriculture include:

1. genetic measures (new crops and varieties that are more tolerant to drought);
2. land reclamation measures (to increase soil water-holding capacity), including manure, increased organic matter, and some polymers;
3. agricultural practices (soil and water conservation through reduced tillage, water harvesting, mulching etc.);
4. the building of new irrigation schemes and the rehabilitation of existing schemes;
5. building knowledge by education for farmers; and
6. raising public awareness of new adaptation techniques.

Some of these measures are used in part by farmers, and some public-awareness activities have been implemented.

### 4.1.4 Soils

Although the country covers just 25,942 km², there is a huge variety of soil cover due to the significant spatial variability of the main pedogenetic factors: geology, vegetation, relief and climate. In the soil map drafted in digital format for the purposes of the present study, the entire territory of the country has been divided into 22 soil types and 27 soil associations (map 5). The most important soil indicators influenced by climate change are reduction in soil organic matter (SOM), soil erosion and salinisation.

### 4.1.5 Vulnerability assessment

Using GIS technology, the digital soil map, the Digital Elevation Model, soil texture classes and climate data, it is possible to determine which areas are vulnerable to SOM decline, soil erosion and salinisation, as presented in maps 6, 7 and 8.
4.1.5.1 Soil adaptation measures

- The application of organic fertilisers (manure, green manure). This measure will maintain, and in many cases increase, the quantity of SOM.
- The development of a system for determining the amount of fertiliser to be applied, based on soil or plant tissue analyses.
- The cultivation of legumes to enrich the soil with nitrogen and raw organic matter and to improve soil structure.
- Crop rotation and fallow periods of several years.
- The constant monitoring of SOM and nitrogen turnover and all necessary parameters in the identified vulnerable region;
- Reduced or no-tillage cultivation.
- The afforestation of sloping terrains that are prone to soil erosion.
- The implementation of new, more efficient irrigation techniques and irrigation at the appropriate time and in appropriate amounts (according to soil capacity).
- The establishment of monitoring at a small number of fully equipped sites, where appropriate soil, climate, topographical and crop/cover data can be collected in order to assess soil erosion and salinisation.
- Building the knowledge and capacity of farmers to manage their land in such a way as to prevent SOM losses, erosion and salinisation.
For this group of adaptation measures the advisory service needs to be trained, after which the advisors will be able to transfer knowledge to the farmers.

5. Socioeconomic impacts

There are two possible scenarios for Macedonian agriculture with respect to climate change. Agriculture can adapt to the impacts of climate change; or it can remain as it is and combat climate change in the same way as it currently struggles against climate variability.

In the first scenario, changes in agriculture could lead to a more environmentally friendly agricultural sector. Production would be lower (that is, there would be a significant decrease in crop production and a slightly lower decrease in livestock production). At the same time, there would be increased attention on environmental issues. A decrease in the agricultural population can be expected, meaning fewer farmers and farms, although farms would become bigger. The productivity and profitability of such farms would be far higher due, for example, to new agricultural practices and measures, the increased application of modern biotechnology and the application of precision farming. The welfare of the country’s rural population would improve and the level of poverty would be reduced.

In the second scenario, with no change in agricultural practice, production in most of the non-irrigated areas will decrease dramatically and in irrigated areas will mostly remain at the same level. Poverty levels will rise in non-irrigated agricultural areas, and inhabitants from these areas will increasingly migrate to areas with higher development levels. Due to the decreased yields climate change will cause severe economic losses. An estimation of economic losses is presented in Table 11. The estimates are based on the assumption that the whole of the country will be affected equally by climate change, and that no adaptation measures will be applied.

The decrease in yield is the average calculated perceived decrease in yield in regions where the crop is considered to be a vulnerable crop. The decrease in yield is calculated based on the assumption that the entire country will be affected by climate change in the same manner and that all areas planted with the crop will be affected by the same decrease in yield. This is a very broad assumption, but is the best available possibility. The numbers presented in the table are no more than rough estimations. For a more accurate analysis a separate project would be needed. Average prices have been used to obtain rough figures for the economic impacts of decreased yields. In the case of winter wheat, the average price used as 8 denars per kg; for grapes 10 denars per kg; and for alfalfa 7 denars per kg.

<table>
<thead>
<tr>
<th>Year</th>
<th>Decrease in production due to climate change (tons)</th>
<th>Cost of decreased production (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter wheat</td>
<td>Grapes</td>
</tr>
<tr>
<td>2025</td>
<td>31,806</td>
<td>112,910</td>
</tr>
<tr>
<td>2050</td>
<td>41,926</td>
<td>122,729</td>
</tr>
<tr>
<td>2075</td>
<td>53,492</td>
<td>135,002</td>
</tr>
<tr>
<td>2100</td>
<td>66,504</td>
<td>144,820</td>
</tr>
</tbody>
</table>

6. Recommendations

In the context of global climate change, agriculture in the former Yugoslav Republic of Macedonia faces significant impacts resulting from changes in the local climate. While not all climate change impacts are necessarily negative (e.g. an increase in arable land in countries located in boreal regions can be anticipated), most changes affecting the former Yugoslav Republic of Macedonia will be negative. It should also be borne in mind that these impacts are already being felt and will aggregate rapidly based on existing scientific knowledge. An increase of around 1°C within the period up to 2025 is more than likely,
as are significant changes in precipitation, including a decline in rainfall during the summer season in the most productive agricultural areas.

Approximately a quarter of the country’s inhabitants are dependent on some form of agricultural income, which is steadily falling. Climate change impacts could therefore undermine the positive role that agriculture and rural development have played during the period of transition from a centralised planned economy towards the independent country’s liberal market economy, a process that is still ongoing. Climate change can affect this process by undermining agricultural income.

Table 10. Estimated economic damage caused by expected climate change in winter

6.1 Gaps and barriers

Key knowledge gaps have been identified, which affect the country’s capacity to respond to climate change. These gaps exist at various levels and affect a range of stakeholders who are responsible for policy-based responses, structural changes, changes in behaviour, and technological and/or managerial responses. Apart from the Ministry of Environment and Physical Planning (MoEPP), where all national activities related to climate change are based, it should be stressed that one of the main constraints is a lack of understanding of climate change issues in the Ministry of Agriculture, Forestry and Water Economy (MAFWE). There are no personnel in either ministry dealing with climate change issues in agriculture. The agricultural sector is therefore particularly vulnerable and faces serious consequences unless structures are addressed and capacities built. Experts working in national research institutions do have an understanding of climate change risks, mitigation and adaptation. However, this expertise cannot be applied in full due to a lack of information and limitations in terms of data collection and analysis, monitoring, thematic approach, structure, possibilities and projects. One of the main problems is the lack of appropriate systems to serve as reliable and constant sources of data for subsequent elaboration by the State Statistical Office. Knowledge of climate change mitigation and adaptation is also lacking at the level of farmers, municipalities and NGOs, and these gaps need to be bridged through education and capacity building.

6.2 Recommendations for decision makers

Policy

1. Multi-criteria assessments should be implemented as a tool for the prioritisation of needs. Some changes should be made to the organisational structure of the relevant ministries and institutions, and governmental officials should be appointed with concrete duties related to climate change in the agricultural sector. Climate change issues should be incorporated in strategic documents related to rural and local economic development.
2. Existing national strategic documents and existing guidelines for the preparation of strategies, programmes and plans at local and national level should be revised to take into account the issue of climate change in the agricultural sector.
3. Policy-based responses require the broader involvement of experts and policy makers from all relevant sectors in order to build a national strategy for climate change adaptation in the agricultural sector. Since limited information is available, this will necessitate undertaking a national study of the problem, covering the different aspects and the possible ways to reduce threats to national food security and to the country’s socioeconomic status and resource reserves. The action plan developed for the national strategy should be accompanied by a budget line for plan implementation and by appropriate decision making.
4. Changes in behaviour can be achieved through continuous public awareness raising, resulting in an increased understanding of climate change adaptation.
Assessment needs

Climate change adaptation will depend to a great extent on adjustments and structural changes at every level, from local to national. It is particularly important to provide good adaptation measures for farmers that can ensure sustainable food production. Such solutions can be promoted at municipality/regional level by mobilising local NGOs, experts and farmers. This will require the establishment of a coordination body that is able to recognise risks to food security well in advance and give recommendations for overcoming them.

Since the impacts of climate change that can already be felt will profoundly affect agricultural development in the country, a better understanding of extreme climate events is needed in addition to that provided by the use of models. It is therefore recommended to:

- develop case studies of heat waves in order to assess their impact on agricultural production and value chains, since anecdotal evidence suggests that significant damage is caused by heat waves to rain-fed crops such as tobacco and grapes; and
- assess, by expanding existing hydrological studies, the effects on irrigation, since less snowfall and more rain will lead to more intense run-off in winter.

Farming monitoring systems (FMS) can provide a better assessment of the anticipated impacts of climate change on agricultural income and farmers’ livelihoods than the existing limited micro-economic impact analyses. The results of FMS could be used for micro-economic and macro-economic modelling. Damage impact assessments should then be adjusted since the existing results do not adequately reflect current farming practices.

A socioeconomic analysis should be undertaken to allow for a better understanding of how agriculture is perceived and what capacity and knowledge are available locally, since farmers possess and are developing ways to address the impacts of climate change.

Interventions

Technological responses are difficult since there is no simple, ready-made solution that can be applied to reduce risks and lessen the damage caused to agriculture by climate change. “These complex processes and competing objectives require careful analysis of biophysical system feedbacks and societal interactions. There is a growing understanding of the possibilities to choose and implement mitigation options in the agriculture sector to realize synergies and avoid conflicts with other dimensions of sustainable development. Mitigation technologies and policies in agriculture should encourage synergies with sustainable development and adaptation to climate change, thereby overcoming barriers to implementation and helping poverty alleviation and food security” (FAO, 2008). However, a provisional set of actions can be undertaken in the form of short-term and long-term interventions.

<table>
<thead>
<tr>
<th>Short-term interventions</th>
<th>Long-term interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Insurance</td>
<td>• Changing the crop/livestock mix</td>
</tr>
<tr>
<td>• Diversifying livelihood portfolios</td>
<td>• Adopting new crops and livestock that are better suited to the anticipated climatic conditions (e.g. drought-tolerant strains)</td>
</tr>
<tr>
<td>• Adjusting the timing of operations</td>
<td>• Irrigation (water management)</td>
</tr>
<tr>
<td>• Changing tillage practices</td>
<td>• More efficient water use</td>
</tr>
<tr>
<td>• Using seasonal forecast information</td>
<td>• Land tenure reform</td>
</tr>
<tr>
<td>• Creating storage facilities (grain and animal-feed reserves at local level)</td>
<td>• Pursuing alternative livelihoods</td>
</tr>
<tr>
<td>• Creating off-farm employment</td>
<td>• Rezoning agriculture</td>
</tr>
<tr>
<td>• Creating grain and animal-feed storage facilities at national level</td>
<td>• Encouraging the systematic use of soil and water conservation measures</td>
</tr>
<tr>
<td>• Setting up or improving famine relief units for the rapid dispersion of food aid</td>
<td></td>
</tr>
<tr>
<td>• Expanding the exploitation of other food</td>
<td></td>
</tr>
</tbody>
</table>
In addition, the contribution of the agricultural sector to GHG emissions must be better understood from the perspective of climate change mitigation. The impacts of floods and droughts must both be analysed. More focused and thorough approaches are required to build understanding and capacity. This will require longer-term research programmes backed up by high-level technical assistance and less stand-alone short-term technical assistance.

An enhanced understanding of the impacts of climate change and GHG emissions will provide the foundations for incorporating climate change issues into agricultural development policies, as long as the political will is in place.

Notes:

1 Second National Communication on Climate Change, the former Yugoslav Republic of Macedonia, 2008
2 Second National Communication on Climate Change, the former Yugoslav Republic of Macedonia, 2008
3 Ministry of Agriculture, Forestry and Water Economy, Annual Report, 2010
4 Second Communication to UNFCCC: Agriculture Sector, the former Yugoslav Republic of Macedonia
5 Second Communication to the UNFCCC: Agricultural Sector, the former Yugoslav Republic of Macedonia
6 Deficit Irrigation Practices –FAO
   www.fao.org/docrep/004/y3655e/y3655e04.htm
Impact of climate change on food production in northern Serbia (Vojvodina)

Branislava Lalic and Dragutin T. Mihailovic
Faculty of Agriculture, University of Novi Sad, Serbia

1. Country overview

Serbia is a developing country with favourable agro-ecological conditions that have made agricultural production a traditionally important part of the national economy. According to the Statistical Office of the Republic of Serbia (Study 76, 2006), agriculture in Serbia accounts for about 11.5 percent of gross value added in 2004. The vulnerability of the overall economy thus depends to a great extent on factors that affect agriculture. Currently, the most significant factor is the impact of climate change on agriculture, which is the subject of this study. The Autonomous Province of Vojvodina (hereafter Vojvodina) is located in northern Serbia and is the most important agricultural area in the country. Serbia, along with Vojvodina, like other Western Balkan countries, has undergone a very turbulent transition period in the last two decades, with huge consequences in many areas, and particularly on agricultural science and practice. During the transition period, no human or other resources were available to estimate the extent of the impact of climate change on food production in Serbia. However, in the last five years, through the activities of the Center for Meteorology and Environmental Predictions (CMEP) and the University of Novi Sad, and two projects implemented under the Sixth EU Framework Programme for Research and Technological Development (FP6), such an analysis has become possible (Mihailovic and Lalic, 2010). The present study, which represents a pioneering work in this field in Serbia, is an attempt to assess and quantify the impact of climate change on food production in Vojvodina.

This study is organised in five sections. Following an introductory section, Section 2 deals with the geographic position and climate of Vojvodina, while Section 3 includes a comprehensive analysis of the actual effects of climate change in Vojvodina. In order to minimise the negative impacts of climate change on food production, we argue that an efficient and sustainable concept of adaptation must be developed for Vojvodina. Some of the basic elements of this concept are suggested in Section 4. Concluding remarks are then made in Section 5. In order to avoid overloading individual sections with information about those climate models of which the outputs were used, this information has been included in the introductory part.

The Global Climate Models (GCMs) used in this study were developed in (1) the UK Hadley Centre for Climate Prediction and Research (HadCM3) (Gordon et al., 2000); (2) the Max-Planck Institute for Meteorology (ECHAM5) (Roeckner et al., 2003); (3) the US National Center for Atmospheric Research (NCAR-PCM) (Washington et al., 2000); and (4) the Atmosphere Ocean Global Circulation Model (SX-G) (Gualdi et al., 2003). The first step in an assessment of climate change impacts on human activities is the downscaling of climate model outputs. For this purpose, statistical and dynamic downscaling techniques are usually used. In order to synthesise the daily data series, the Met&Roll weather generator (Dubrovsky, 1996; Dubrovsky, 1997) has been used for the statistical downscaling of the HadCM3, ECHAM5 and NCAR-PCM climate model outputs integrated using the A2 scenario for two integration periods (2040 and 2080). Using the Coupled Regional Climate Model (CRCM) EBU-POM for the dynamic downscaling of SX-G, climate projections for the periods 2001 to 2030 and 2071 to 2100 are also performed using A1B and A2 scenarios (Djurdjevic and Rajkovic, 2008).

To assess the impacts of climate change on winter wheat growth and yield in Vojvodina, we have used the dynamic crop growth simulation model SIRIUS (Jamieson et al., 1998; Semenov and Porter, 1995), which has already been calibrated and validated for the agro-ecological conditions in Vojvodina (Lalic, 2006; Lalic et al., 2007; Lalic et al., 2008; Lalic et al., 2009). This was done for six meteorological stations, uniformly distributed throughout Vojvodina, by calculating the relative change in grain yield with the daily generated data series. In addition, we provide an assessment of climate change impacts on vineyard regionalisation following the methodology suggested by Vukovic et al. (2010).
2. The geographic position and climate of Vojvodina

Vojvodina is a mostly flat area located in the southern part of the Pannonian lowland. Vojvodina has a continental climate, with some elements of a sub-humid and thermal climate (Katic et al., 1979). According to Katic et al., the short distance between the northern and southern areas (up to 2 degrees of latitude), and the fact that this area is remarkably uniform in terms of geography (with the exception of the Fruska Gora mountain), mean that there are no really pronounced temperature differences between areas in Vojvodina. As part of the Pannonian lowland, Vojvodina is surrounded by mountains, which have a significant impact on its basic climate characteristics. However, its exposure to the air masses coming from the north and west, together with the big range of temperatures throughout the year, mean that the continental characteristics of Vojvodina’s climate are more pronounced, particularly in the summer and winter. According to Koppen’s climate classification, the climate formula for Vojvodina has the form Cfwbx (Mihailovic, 1988; Mihailovic et al., 2008). The first letter in the formula is C, indicating a moderately warm and rainy climate (the mean temperature of the coldest month is in the range -3.0°C to -18°C [January -0.7°C]; the mean temperature of the warmest month is greater than 10.0°C [July, 21.4°C]). The second letter in the formula is f, indicating that the maximum precipitation occurs in summer (June: 80 mm), while the letter w indicates the minimum rainfall in the cold part of the year (March, 37 mm). The letter b in Koppen’s formula indicates hot summers (the mean temperature of the warmest month is in the range of 10°C to 22°C [July, 21.4°C] and the duration of the period with mean monthly temperature above or equal to 10°C over four months [seven months between April and November]). The last letter, x, indicates that in this climate subtype secondary maximum precipitation appears in the late fall (November and December). The annual mean temperature is 11°C and the mean annual precipitation is 602 mm (Mihailovic et al., 2004).

Figure 1: Soil map of Vojvodina region

The soil map of Vojvodina (Zivkovic et al., 1972) indicates 20 different soil types (Figure 1) with chernozem as the prevailing type, covering 43 percent of the cultivated area of the region with almost uniform distribution.
3. Actual effects of climate change in Vojvodina

Since climate variability is originally a natural phenomenon, assessing climate change effects is not an easy task. The visibility of these effects can be classified in respect to: (a) changes in precipitation regime; (b) variations in air temperature and amounts of precipitation; and (c) the frequency and intensity of extreme weather events.

3.1 Climate change in Vojvodina: Current state

Six meteorological stations were selected for the study (Table 1), located in areas in which chernozem soil is the dominant soil type surrounding the stations. The data for the period 1985 to 2005, used in the crop modelling study, were taken from meteorological stations located in rural areas that provide continuous daily data, including maximum and minimum temperatures, sunshine duration, precipitation, mean daily water vapour pressure and wind speed.

Table 1: Annual precipitation and temperature for the period 1985 to 2005, with the geographical coordinates of the meteorological stations.

<table>
<thead>
<tr>
<th>Station</th>
<th>Coordinates</th>
<th>Annual precipitation (mm)</th>
<th>Annual temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palic (PA)</td>
<td>46° 45' N 19° 45' E</td>
<td>552.7</td>
<td>11.4</td>
</tr>
<tr>
<td>Sombor (SO)</td>
<td>45° 47' N 19° 08' E</td>
<td>604.6</td>
<td>11.5</td>
</tr>
<tr>
<td>Kikinda (Kl)</td>
<td>45° 50' N 20° 27' E</td>
<td>542.2</td>
<td>11.6</td>
</tr>
<tr>
<td>Novi Sad (NS)</td>
<td>45° 15' N 19° 50' E</td>
<td>639.3</td>
<td>11.7</td>
</tr>
<tr>
<td>Zrenjanin (ZR)</td>
<td>45° 22' N 20° 23' E</td>
<td>574.4</td>
<td>11.7</td>
</tr>
<tr>
<td>Banatski Karlovac (BK)</td>
<td>45° 3' N 21° 1' E</td>
<td>602.2</td>
<td>11.8</td>
</tr>
</tbody>
</table>

The weather conditions in the selected locations were significantly different during the period 1995 to 2005, compared to the period 1985 to 2005 (Figure 2). During the 1995 to 2005 period, precipitation records indicate both positive and negative trends with a strong temperature gradient in the SE–NW direction. One possible explanation for the occurrence of these trends is the increased number of extreme weather events during the 1995 to 2005 period.

Table 2: Number of days with extreme air temperatures (°C) for the 1985 to 1995 and 1995 to 2005 periods in Vojvodina.

<table>
<thead>
<tr>
<th>Stations</th>
<th>March: frost days</th>
<th>April: frost days</th>
<th>May: tropical days</th>
<th>May: summer days</th>
<th>June: tropical days</th>
<th>June: summer days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>85-95</td>
<td>95-05</td>
<td>85-95</td>
<td>95-05</td>
<td>85-95</td>
<td>95-05</td>
</tr>
<tr>
<td>Banatski Karlovac</td>
<td>98</td>
<td>125</td>
<td>15</td>
<td>18</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>Kikinda</td>
<td>97</td>
<td>128</td>
<td>14</td>
<td>22</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>Palic</td>
<td>85</td>
<td>123</td>
<td>13</td>
<td>18</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>Novi Sad</td>
<td>94</td>
<td>136</td>
<td>15</td>
<td>20</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Sombor</td>
<td>105</td>
<td>138</td>
<td>17</td>
<td>26</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td>Zrenjanin</td>
<td>96</td>
<td>123</td>
<td>15</td>
<td>21</td>
<td>7</td>
<td>23</td>
</tr>
</tbody>
</table>

Figure 2: Trends in mean annual temperature (°C) (a, c) and annual precipitation (mm) (b, d) (1985-2005) and (1995-2005) periods in Vojvodina.
For example, in Novi Sad in 1999, due to a few extreme precipitation events, annual precipitation was 50 percent above the long-term average, while in 2000 annual precipitation was 50 percent below the long-term average due to a very dry spring and summer. Additionally, during the 1995 to 2005 period, warmer winters and the increased frequency of spring frosts (the number of frost days in March and April) are accompanied by warm periods during the spring and an increased number of tropical and summer days in May and June (Table 2). It should be noted that the proportion of frost days in March and April was higher, on average, by 33 percent and 6 percent respectively, while the proportion of tropical and summer days between May and September varied as indicated below:

- tropical days in May: 17.7 percent
- summer days in May: 37.3 percent
- tropical days in June: 43.8 percent
- summer days in June: 40.3 percent
- tropical days in July: -27.0 percent
- summer days in July: -23.7 percent
- tropical days in August: -22.0 percent
- summer days in August: 9.3 percent
- tropical days in September: -18.3 percent
- summer days in September: -31.2 percent

The number of extremely hot days obviously increased in the first half of the year and decreased in the second half. This means that the whole of the spring and the first summer months are more influenced by extreme weather events. In order to assess the acceleration of climate change in Vojvodina, we analysed the variation in maximum and minimum temperatures; and the mean annual temperature and precipitation for the periods 1951 to 1981 and 1981 to 2005 (Lalic et al., 2011). This analysis clearly indicates (Table 3) that increased variation is the most pronounced characteristic of climate change in Vojvodina during the last decades, especially in the case of precipitation. The increased number of extreme weather events and variation in precipitation are common characteristics of the current state of climate change in Vojvodina.
Table 3: Coefficient of the variation of maximum (Vt$_{\text{max}}$), minimum (Vt$_{\text{min}}$) and mean annual (Vt$_d$) temperature and precipitation (VH) for the periods 1951 to 1981 and 1981 to 2005 in Vojvodina.

<table>
<thead>
<tr>
<th>Station</th>
<th>Vt$_{\text{max}}$ (%)</th>
<th>Vt$_{\text{min}}$ (%)</th>
<th>Vt$_d$ (%)</th>
<th>VH (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 51-81</td>
<td>81-05</td>
<td>81-05</td>
<td>51-81</td>
<td>81-05</td>
</tr>
<tr>
<td>Vrsac</td>
<td>4.40</td>
<td>5.15</td>
<td>11.32</td>
<td>10.52</td>
</tr>
<tr>
<td>Kikinda</td>
<td>5.27</td>
<td>5.58</td>
<td>9.54</td>
<td>10.12</td>
</tr>
<tr>
<td>Palic</td>
<td>5.30</td>
<td>6.29</td>
<td>9.53</td>
<td>10.50</td>
</tr>
<tr>
<td>Novi Sad</td>
<td>4.89</td>
<td>5.83</td>
<td>10.02</td>
<td>11.14</td>
</tr>
<tr>
<td>Sombor</td>
<td>5.15</td>
<td>5.95</td>
<td>11.64</td>
<td>10.10</td>
</tr>
<tr>
<td>Zrenjanin</td>
<td>4.91</td>
<td>5.45</td>
<td>10.88</td>
<td>10.94</td>
</tr>
</tbody>
</table>

3.2 Impact of climate change on food production: Current state

Through an illustrative survey, we highlight below the impacts of climate change on food production in Vojvodina over the last 25 years. The data gathered for fruits and crops are summarised in three tables and one illustrative graph, which provide a clear and concise picture of the damage caused as a consequence of extreme events that are part of climate change. The highest yield losses caused by natural conditions in Vojvodina can be seen through the following extreme weather events: drought, spring frosts, hail and floods. Tables 4 and 5 and Figure 3 indicate the areas damaged by late frosts in orchards in the period 2002 to 2003 (Table 4); and by hail on crop fields in the period 1986 to 2000 (Table 5). At present, we have no available data indicating the damage to food production caused by floods, since the systematisation of such data at state level is still in progress. This aspect has not therefore been included in the present analysis.

Table 4: Area of orchard (ha) damaged by spring frost in Vojvodina in the period 2002 to 2003. (Source: Provincial Secretariat for Agriculture, Water Management and Forestry of the Autonomous Province of Vojvodina; personal communication.)

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>County</td>
<td>Apple</td>
<td>Pear</td>
<td>Apricot</td>
<td>Peach</td>
<td>Vine fruit</td>
<td>Cherry</td>
<td>Nut</td>
<td>Plum</td>
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<tr>
<td>B.Topola</td>
<td>44</td>
<td>28</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senta</td>
<td>628</td>
<td>628</td>
<td>489</td>
<td>25</td>
<td></td>
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</tr>
<tr>
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<td>24</td>
<td>17</td>
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<tr>
<td>Pancevo</td>
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<td>21</td>
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<tr>
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<tr>
<td>Subotica</td>
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<td>92</td>
<td>182</td>
<td>211</td>
<td>66</td>
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<tr>
<td>Irig</td>
<td>480</td>
<td>294</td>
<td>20</td>
<td>272</td>
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<tr>
<td>Ruma</td>
<td>160</td>
<td>90</td>
<td>10</td>
<td>270</td>
<td></td>
<td>20</td>
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<tr>
<td>Kvin</td>
<td>35</td>
<td>10</td>
<td>3</td>
<td></td>
<td>45</td>
<td>4</td>
<td>28</td>
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<tr>
<td>Odcaci</td>
<td>282</td>
<td></td>
<td>250</td>
<td>67</td>
<td>40</td>
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<tr>
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<td>67</td>
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<tr>
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<td>Total:</td>
<td>4236</td>
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<td>897</td>
<td>1496</td>
<td>2092</td>
<td>320</td>
<td>94</td>
<td>239</td>
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</tbody>
</table>

Table 5: Area of orchard (ha) damaged by hail in Vojvodina in the period 1986 to 2000. (Source: Provincial Secretariat for Agriculture, Water Management and Forestry of the Autonomous Province of Vojvodina; personal communication.)

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<tr>
<td>County</td>
<td>Apple</td>
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<td>Peach</td>
<td>Vine fruit</td>
<td>Cherry</td>
<td>Nut</td>
<td>Plum</td>
<td>Quince</td>
</tr>
<tr>
<td>B.Topola</td>
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<td>Zrenjanin</td>
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<td>20</td>
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</tr>
</tbody>
</table>

85
It is well known that extremely low temperatures in early spring, followed by a short period in which air temperature is above the mean value, can seriously damage the early growing varieties of fruits, grapes and some crops due to the earlier start of the growing season. From this point of view, the years 2002 and 2003 are particularly interesting for the present analysis. According to reports issued by agricultural advisory services, spring frost events in 2002 and 2003 seriously damaged many orchards with different varieties.

A brief look at Table 4 indicates that the greatest damage caused by spring frost was in apple orchards (in 15 counties) on 4,236 ha in 2002 and 2,160 ha in 2003. The next highest level of damage after apple orchards is to vine fruits (2,092 ha in 2002 and 1,494 ha in 2003). It should be noted that spring frost damage to sugar beet in 2003 was observed on 33,669 ha. This was some of the most extensive damage caused by frost in food production in Vojvodina, viewed in terms of absolute as well as relative amounts.

**Figure 3:** Area of orchards (ha) damaged by spring frost in Vojvodina in the period 2002 to 2003. (Source: Provincial Secretariat for Agriculture, Water Management and Forestry of the Autonomous Province of Vojvodina; personal communication.)

Compared to drought, which is relatively infrequent, hailstorms occur almost every year causing enormous damage to food production. Losses caused by hail in the period 1986 to 2000 to wheat, sunflower, maize and sugar beet fields in Vojvodina are shown in Table 5 (Stokuca, 2006). The figures in this table indicate that the biggest loss caused by hail (estimated in USD) was to wheat (31,430,250) followed by sunflower (15,419,407), sugar beet (17,699,490) and maize (16,260,707), representing a significant cost to Vojvodina’s food production capacities in the indicated period.

The above analysis provides concise information about the impacts of climate change on food production in Vojvodina arising from direct damage — that is, as a result of extreme events and other climate change effects. However, damage caused by climate change can also be indirect, for example through changes in the prevailing structure of pests and plant diseases in the relevant agricultural region.
The gathering of this kind of information is difficult and sensitive in terms of the reliability of the data. The on-site observations of farmers and agricultural professionals are therefore a valuable source of information about the effects of climate change on pests and plant diseases. In the framework of the FP6 ADAGIO project (2007-2009), we carried out interviews in 13 agricultural advisory services involving 199 experts. Another series of interviews was carried out with farmers (972), although this is not included in the analysis since it has a different structure. A carefully designed questionnaire was distributed to the experts, in which they were asked for their observations and opinions regarding changes in the appearance of pests and plant diseases over the last 10 years that could potentially be connected to climate change.

Table 5: Crop yield losses caused by hail in Vojvodina in the period 1986 to 2000 (Source: Statistical Bulletin of the insurance company DDOR Novi Sad, a.d.)

<table>
<thead>
<tr>
<th>Period</th>
<th>Damaged area (ha)</th>
<th>Yield losses (t)</th>
<th>Yield losses (USD)</th>
<th>Damaged area (ha)</th>
<th>Yield losses (t)</th>
<th>Yield losses (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Maize</td>
<td>Sunflower</td>
<td>Sugar beet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986-1990</td>
<td>16,784</td>
<td>85,162</td>
<td>12,774,300</td>
<td>14,848</td>
<td>73,245</td>
<td>9,448,605</td>
</tr>
<tr>
<td>1991-1995</td>
<td>11,610</td>
<td>49,319</td>
<td>7,397,850</td>
<td>4,193</td>
<td>18,969</td>
<td>2,447,000</td>
</tr>
<tr>
<td>1996-2000</td>
<td>20,642</td>
<td>75,054</td>
<td>11,258,100</td>
<td>7,215</td>
<td>33,838</td>
<td>4,365,102</td>
</tr>
</tbody>
</table>

The questionnaires were analysed and the experts’ answers were classified to indicate potential climate change in Vojvodina (Eitzinger et al., 2009; Mihailovic et al., 2010). This underlined the following facts:

(a) During the last 10 years, the more frequent and intensive appearance of powdery mildew on cereals, Fusarium head blight, Cercospora leaf spot, sunflower blight, and potato and tomato Alternaria spot leaf was observed. These are all indicators of changed climate conditions, since their development requires high night temperatures in spring and high temperatures in summer, accompanied by showers.

(b) Fruit production is particularly vulnerable to the increased frequency of extreme weather events such as spring frost, hail, extremely low winter temperatures, lack of precipitation (in particular in July and August) and/or extremely high precipitation intensity during the growing season.

(c) The vegetation period for winter and summer crops is becoming shorter due to the trend towards temperatures above the biological minimum (2003, 2007, 2008). Although these conditions significantly affect plant growth, they do not necessarily lead to a decrease in yield. In the case of thermophile summer plants, high temperatures should not negatively affect development, although big variations in temperature can cause significant plant stress and increase vulnerability to pests and diseases.

(d) Damage spots influenced by high solar radiation intensity and high temperatures can be frequently observed on fruits and vegetables.

4. Projected effects of climate change in Vojvodina

4.1 Climate change in Vojvodina: Climate model projections

According to all GCMs, the countries of South Eastern Europe (equivalent to the Western Balkans) are facing serious climate change impacts (Chimicilevski and Rotzer, 2002; Vidale et al., 2007), resulting in the increased frequency of extreme weather events and significant changes in the rate and amplitude of meteorological elements.

to 2030 (SRES A1B scenario) and 2071 to 2100 (A2 scenario), with 1961 to 1990 as the reference data set. The model domain was the region of Europe; and the model resolution was approximately 30 km. Figure 4 shows that for the whole of Serbia temperatures rose in the first 30 years (2001 to 2030) about 1°C (upper left); and in the last 30 years (2071 to 2100) more than 3°C (upper right panel).

**Figure 4:** Differences in mean annual air temperature for the periods 2001 to 2030 (upper left) and 2071 to 2100 (upper right), and the value for the period 1961 to 1990 in degrees; and the same differences for precipitation (lower panels) in mm (Source: Djurdjevic and Rajkovic, 2008).

In the first 30 years (lower left) of the 21st century, the expected change in the amount of precipitation for Serbia is positive (20 to 30 mm/year), while for the last 30 years (lower right) the whole country is far drier (with a decrease in precipitation of up to 30 mm/year), with the exception of Vojvodina. Since this region is part of the Pannonian lowland, this deviation can be explained by the significant bias in climate models in the area of the Pannonian lowland, which is a specific model feature typical of many regional climate models, and also to a smaller extent visible in GCMs (Hagemann et al., 2004). It should be noted that the term “summer drying problem in South Eastern Europe (SDP)” is related to the too dry and too warm simulation of the climate over South Eastern Europe during the summer, which is in contrast with the results presented in Figure 4. However, both results indicate that the area of the Pannonian lowland is controversial from a climate simulation point of view, and that future climate scenarios should be carefully analysed.

<table>
<thead>
<tr>
<th>Climate model</th>
<th>Integration period</th>
</tr>
</thead>
<tbody>
<tr>
<td>HadCM3</td>
<td>2040</td>
</tr>
<tr>
<td>ECHAM5</td>
<td>2080</td>
</tr>
<tr>
<td>NCAR-PCM</td>
<td></td>
</tr>
</tbody>
</table>
Statistical downscaling of climate scenarios. In order to assess the impacts of climate change on food production in Vojvodina, we use the outputs from the HadCM3, ECHAM5 and NCAR-PCM climate models (Lalic, 2006; Lalic et al., 2007; Lalic et al., 2008; Lalic et al., 2009). From the six GHG emissions scenarios presented in the IPCC Third Assessment Report for the coming century, SRES-A2 was chosen since it is the “worst” emissions scenario and consequently the greatest climate change signal that can be expected. The three GCMs used in the study are integrated for two periods: 2040 and 2080. Table 6 indicates the denotation used for each data series, the appropriate climate model and the integration period. In order to obtain a finer spatial and temporal resolution of climate model outputs, the statistical downscaling technique based on a weather generator was applied. For the calibration and validation of the Met&Roll weather generator (Dubrovsky, 1996), four variable weather data series for six selected meteorological stations in Vojvodina were analysed.

Figure 5: Relative change (%) in mean annual temperature for 2040 and 2080 compared to the 1985 to 2005 reference period.

Figure 6: Relative change (%) in mean temperature during the growing season for spring crops for 2040 and 2080, compared to the 1985 to 2005 reference period.
Figure 7: Relative change (%) in annual precipitation for 2040 and 2080 compared to the 1985 to 2005 reference period.

According to the GCMs used, annual temperatures in Vojvodina are expected to rise by 1.3°C in 2040, and 2.4°C in 2080. Figure 5 clearly shows that there are no significant differences among climate models (1 or 2 percent maximum) in the projected relative change in annual temperatures. (Similar behaviour will be discussed later for the relative change in temperature during the vegetation period for winter and spring crops.) Annual temperatures in 2040 are expected to be between 9.4 and 12.4 percent higher, while in 2080 they are expected to be between 19.3 and 22.6 percent higher relative to the reference period. Accumulated temperatures above 0°C, during the winter wheat vegetation period in Vojvodina (October to June) are expected to be 8.6 to 12 percent higher in 2040; and 17.8 to 25.67 percent higher in 2080.

The mean air temperature during the winter wheat growing season is predicted to be 10.5 to 15.5 percent higher in 2040, and 21.7 to 28.0 percent higher in 2080, depending on the climate model and location. However, spring crops are more vulnerable to an increased number of crop drying days and projected higher temperatures in the late spring and summer (Figure 6). According to the results obtained, during the spring crops growing season a temperature increase of 4.9 to 8.9 percent for 2040 and of 10.8 to 16.6 percent for 2080 is projected.

The projection of precipitation is a specific problem in climate modelling. In contrast to temperature projection, differences among models in the case of precipitation trends are between 4 and 8 percent.
According to all GCMs used in the study, annual precipitation for 2040 is expected to decrease only slightly, between 0.94 percent (HadCM3) and 10.9 percent (ECHAM5) with significant amplitude, especially during the spring crop vegetation period (April to October). The relative change in annual precipitation for 2040 and 2080 in comparison to the 1985 to 2005 reference period is presented in Figure 7. Since the most significant decrease in precipitation is expected in the summer, it is not surprising that accumulated precipitation during the winter wheat vegetation period is expected to increase (by 4.8 percent) in Kikinda according to HadCM3, to and decrease (by 4.7 percent) in Novi Sad according to ECHAM5, with a non-uniform spatial and temporal distribution and an increased number of crop drying days. On the other hand, a more pronounced decrease in precipitation is projected for the spring crops vegetation period, when a decrease of between 10.2 and 21.9 percent was expected for 2040, while in 2080 it is expected to be between 17.1 and 31.9 percent relative to the 1985 to 2005 reference period (Figure 8).

Figure 8: Relative change (%) in precipitation during the spring crops growing season for 2040 and 2080 compared to the 1985 to 2005 reference period.

4.2 Climate change impacts on food production: Assessment based on climate model projections

Climate change impacts on winter wheat yields were calculated using the wheat simulation model SIRIUS (Semenov and Porter, 1995). This model calculates biomass production from intercepted photosynthetically active radiation (PAR) and grain growth from simple partitioning rules, while the leaf area index (LAI) is developed from a thermal time sub-model. Phenological development is calculated from the main-stem leaf appearance rate and final leaf number, with the latter determined by responses to day length and vernalisation. The effects of water and nitrogen deficits are calculated through their influence on LAI development and radiation use efficiency (Jamieson et al., 1998).

The SIRIUS crop model was run for the whole region using statistically downscaled climate model outputs for three CO₂ concentrations: 330 ppm for both integration periods; 550 ppm for 2040; and 1,050 ppm for 2080. Firstly, crop simulations were performed with climate change effects only — that is, including just air temperature, precipitation and solar radiation impacts on yield. The atmospheric CO₂ concentration was assumed to be 330 ppm for the baseline (1985 to 2005) and for the expected climate. As the next step, simulations were performed supposing a CO₂ concentration of 550 ppm for the year
2040 and 1,050 ppm for 2080 according to the SRES-A2 scenario indicated in the IPCC Third Assessment Report (Watson et al., 2001).

One crucial aspect of the analysis of climate change impacts on food production is the impact of CO$_2$ concentrations on winter wheat yield. In the results of many studies (see, for example, Eitzinger et al., 2009), it is stressed that the positive impact of CO$_2$ increase on winter crop yield can overcome the negative impact of changed climate conditions. The indirect effect of climate change (without the CO$_2$ effect) has mainly negative impacts on crop yields, mostly by increasing the development rate. Also, due to increasing temperatures and corresponding changes in water balance, a shift in the potential production areas of different crops is expected (e.g. maize, potato, soybean, sugar beet).

**Figure 9**: Relative change (%) in winter wheat yield on chernozem soil with CO$_2$ concentration of 330 ppm for 2040 and 2080, compared to the 1985 to 2005 reference period.

In Vojvodina, the results obtained for climate change impacts on relative changes in winter wheat yield on chernozem soil are presented in Figure 9.

According to all the climate models used, a decrease in winter wheat yield of between 3.7 and 16.8 percent is projected for 2040. One exception is the projection made by NCAR-PCM for the Palic region, where an increase of 11.35 percent is expected. For 2080, a significant positive and negative change in yield is obtained depending on the model used. For example, following the HadCM3 model, a decrease in yield through the whole region is expected (of between 5.8 and 19.1 percent), while the ECHAM5 and NCAR-PCM models projected positive relative changes in the Palic region (of 8.73 percent and 6.86 percent respectively) and a negative change in the rest of the region (-16.1 percent and -13.6 percent respectively).

The direct effect of CO$_2$ on winter wheat yield is mostly compensated by the negative indirect effects, in particular for C3 crops, producing a positive yield effect. Results obtained for Vojvodina, with changes in CO$_2$ concentration taken into account, are presented in Figure 10. It can be seen that the expected change in CO$_2$ concentration of 550 ppm for 2040 produces a less pronounced decrease (of 1.4 percent according to ECHAM5 in Zrenjanin County), or even an increase (of 32.7 percent according to NCAR-PCM in the Palic region) in the winter wheat yield. For 2080, according to all GCMs, an increase in yield is expected in the range of 28 percent to 73.6 percent.

**Climate change impact of vineyard regionalisation.** Using climate projections obtained by Djurdjevic and Rajkovic (2008) for the periods 2001 to 2030 (A1B) and 2071 to 2100 (A2), with 1961 to
1990 (experiment 20c3m) as reference period, Vukovic et al. (2010) analysed the impacts of climate change on vineyard regionalisation. Their assessment was based on the calculation of the heliothermal, drought and cool night index. The results obtained indicate that vineyard regions show a tendency to become warmer and dryer. In the 2001 to 2030 period, this effect will be less pronounced, but during the 2071 to 2100 period, grapes will be affected by the high temperatures and precipitation deficit during the growing season, with a specific impact on growth dynamics. Also, in the case of late varieties, high temperatures will have a negative effect on skin colour and the aroma of the grapes and wine.

**Figure 10:** Relative change (%) in winter wheat yield on chernozem soil with CO$_2$ concentration of 550 ppm for 2040 and 1,050 ppm for 2080, compared to the 1985 to 2005 reference period.

### 4.3 Climate change impacts on food production: Adaptation options

Since mitigation techniques have not been very successful to date, adaptation to the increased variability of precipitation and temperature is one of the most important challenges for agriculture in the forthcoming centuries. Some of the adaptation techniques summarised in the ADAGIO project report (Eitzinger et al., 2009) can be used as background information for a sustainable adaptation concept. Bearing in mind changes that have already been observed and changes projected by models, and the main vulnerabilities in food production, some of the most effective adaptation options will be summarised below.

**Reduction in evapotranspiration.** Since variations in, and the unfavourable distribution of, precipitation during the growing season are the most pronounced features of climate change in Vojvodina, protection against evapotranspiration is very important. A reduction in evapotranspiration can be achieved by a reduction in wind speed (using hedgerows and windbreaks); an increase in soil conductivity (mulching); and a reduction in available energy (shading). Effective shading can be achieved by anti-hail nets (where possible), which are, at the same time, an effective method of protection against hail. However, in the case of large variations in canopy temperature and humidity, nets can create a more stable microclimate, reducing the drought stress of plants.

**Crop- and soil-related measures.** Crop-related adaptation measures should be focused on the adaptation of crop rotation; the reduction of spring crops; an increase in the area of winter crops (for better use of soil water); the adaptation of the crop-growing period; and the introduction of new crops
and cultivars with better drought tolerance and water use efficiency. In order to increase soil water storage capacity, it is necessary to reduce soil cultivation and improve soil structure.

**Policy-level adaptation measures.** Besides the farm-level adaptation options indicated above, there are some measures that can be carried out only at regional or country level. Among the most important are the improvement or development of operational monitoring systems (for weather extremes, pests and diseases); and the improvement of information systems and know-how among farmers and agricultural advisors about climate change impacts, natural systems, the sustainability of production and efficient low-cost adaptation measures. It is also important to improve links between research and practice (that is, between scientists, advisors and teachers) and to support breeders to improve the genetic diversity of crops. At regional and national level, the long-term management of natural resources (irrigation infrastructure, for example) should be improved and increased land use diversity should be encouraged.

### 5. Concluding remarks

There is a significant difference in weather conditions in Vojvodina during the 1995 to 2005 period compared to the 1985 to 2005 reference period. Precipitation records indicate positive and negative trends, while a strong temperature gradient in the SE-NW direction can be observed. In addition, during the 1995 to 2005 period, warmer winters and an increased frequency of spring frost are accompanied by warm periods during the spring and an increased number of extreme weather events. It should be noted that the number of extremely hot days increased in the first half of the year and decreased in the second half. This led to increased variation being the most pronounced characteristic of the climate in Vojvodina during the last decades of the 20th century, particularly with respect to precipitation. An increased number of extreme weather events and variations in precipitation are common features of the current state of climate change in Vojvodina.

From the agricultural point of view, the greatest naturally caused agricultural losses in Vojvodina are related to extreme weather events (drought, spring frost, hail, floods). Changed climate conditions also contributed to the change in the structure of pests and plant diseases that was registered in recent years.

According to results based on the dynamic downscaling of the SX-G climate model, temperatures in Serbia will increase by 1°C in the 2001 to 2030 period; and by more than 3°C in the 2071 to 2100 period. In the first 30 years of the 21st century, the expected change in the amount of precipitation in Serbia is positive (20 to 30 mm/year), while for the last 30 years the country as a whole will be much drier (with a decrease in precipitation of up to 30 mm/year), with the exception of Vojvodina.

According to the statistically downscaled outputs of HadCM3, ECHAM5 and NCAR-PCM, annual temperatures in Vojvodina are expected to rise by 1.3°C by 2040; and by 2.4°C by 2080. There are no significant differences among climate models in the projected relative change in annual temperature. Accumulated temperatures above 0°C during the winter wheat vegetation period in Vojvodina (October to June) are expected to be 8.6 to 12 percent higher in 2040 and 17.8 to 25.67 percent higher in 2080. The mean air temperature during the winter wheat vegetation period is expected to be 10.5 to 15.5 percent higher in 2040; and 21.7 to 28.0 percent higher in 2080, depending on the climate model and location. Spring crops will be more affected by the increased number of crop drying days and the projected higher temperatures during the late spring and summer. According to the results obtained, during the spring crops growing season a temperature increase from 4.9 to 8.9 percent is projected for 2040 and from 10.8 to 16.6 percent for 2080.

Following the SIRIUS crop model, which was run with statistically downscaled GCM outputs, it seems that the winter wheat yield will generally decrease in the absence of a significant increase in CO₂ concentration. However, anticipating climate change effects without a change in CO₂ concentration is not very reasonable. Hence, taking into account CO₂ impacts, a significant increase in winter wheat yield can be expected in the range of 28 to 73.6 percent.

Regarding adaptation strategy, it is important to take into account the numerous economic, legal and institutional limitations that affect the application of appropriate adaptation measures. The most important economic problems are related to the high costs of introduction, unfavourable bank credits and the undeveloped market. Additionally, farmers have no influence on the prices of inputs and outputs; and subventions for plant production are very limited and highly dependent on the trade sector. It should be noted that the privatisation of the food industry is still not complete, which is a source of additional problems. For these reasons, and in this phase of realisation, the planned adaptation measures should be
focused on reducing evapotranspiration; crop rotation; decreasing spring crops and increasing winter crops in order to make better use of soil water; reducing soil cultivation and improving soil structure; changing sowing dates; and changing crops and cultivars to less demanding varieties. In terms of vine quality and production, the direction of changes should be towards more adaptable varieties and vineyard regionalisation, in which production areas will be shifted to regions at higher altitudes that have a more appropriate climate for existing varieties.

By way of conclusion, it can be stated that there are a huge number of steps that could improve agricultural adaptation to climate change, which can be taken in spite of the current economic problems in Serbia.

Acknowledgements

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6. Literature


The scenarios described in the SRES report are grouped into four scenario families (A1B, A2, B1 and B2) that explore alternative development pathways covering a wide range of demographic, economic and technological driving forces and their resulting GHG emissions.

A1B refers to a scenario in which technological development is assumed, but both fossil and non-fossil energy sources will be used in balance. The A2 scenario describes a very heterogeneous world with high population growth, slow economic development and slow technological change.