NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 32, 2015
Print ISSN 1222-4227; Online ISSN 2067-5720

CLIMATE CHANGE IMPACTS ON AGRICULTURAL CROPS IN THE TIMIŞ PLAIN, ROMANIA

Bianca Mitrică[1], Elena Mateescu[2], Carmen-Sofia Dragotă[1], Ines Grigorescu[1*], Monica Dumitraşcu[1], Elena-Ana Popovici[1]

[1]Institute of Geography, Romanian Academy, Romania
[2]National Meteorological Administration, Romania
[*] Corresponding author. E-mail: inesgrigorescu@yahoo.com

ABSTRACT

The paper is aiming to assess the climate change impacts on crop production in Timiş Plain – one of the most stable areas in terms of future climate change signals, using the CERES (Crop-Environment Resource Synthesis) model. This model combines database (climate, soil and crop) with simulation algorithms of the main processes related to crop pattern and statistical algorithms for biophysical, economic and strategic analysis. For the current research, the authors used two applications of CERES model: CERES-Wheat and CERES-Maize, overlapping two regional climatic scenarios for 2021-2050 and 2071-2100 periods. The models describe, on a daily data basis, the main biophysical processes witch occur at the soil-plant-atmosphere interface as a response to the variability of different processes such as: photosynthesis, specific phenological phases, evapotranspiration, water dynamics in soil etc. The winter wheat benefits from the interaction between the CO_2 and air temperature increase, while the maize is more vulnerable to climate change, especially to hot and dry climate over the 2071-2100 period, under the SRES A1B scenario. Even though the study-area does not experience strong climate change signals, however, against the current climatic conditions, temperature rise, especially in the conditions of the second future projected period, brings about a decrease of the vegetation period for both crops. Consequently, the increase of atmospheric CO_2 concentration has a positive effect on photosynthesis for winter wheat triggering increased yields, thus counteracting the negative effect of shortening the vegetation period. In the case of maize, the yields are subject to shrinkages, more acute over the 2071-2100 period, due to temperature rise and shortening of the vegetation period, coupled with water stress, especially during the flowering and yield formation interval.

Key words: crop production, CERES model, climate change, Timiş Plain, Romania.

INTRODUCTION

The climate change impacts on agriculture are the result of a series of complex interactions with other environmental, social, economic and political factors (Mitrică et al., 2013) and are mainly related to the biological effects on crop yields, as well as the resulting impacts on outcomes including prices, production, and consumption (Nelson et al., 2009). Thus, acknowledging and assessing the most important drivers of change in agriculture, one may be able to project future agricultural productions under certain economic, environmental, and social scenarios in order to minimize negative impacts, especially under certain climate change scenarios (Entwisle and Stern, 2005). Consequently, relating agriculture with models simulation of the potential impact of climate change on crop production is a very important issue, particularly under the current conditions when natural resources and food supplies are shrinking in many regions of the world (Mitrică et al., 2013).

Climate changes signals recognised by the scientific community worldwide usually refer to changes in temperature and precipitation patters as well as to the increasing intensity and occurrence of extreme weather events, such as extended intervals with temperatures specific for the warm/cold semester, prolonged droughts, extreme heat and aridity phenomena, heavy rainfall, severe wind storms etc. (Busuioc et al., 2010a; Hov et al., 2013).

The latest IPCC Report, relying on both observational data at global scale and climate models simulations, recalls an accelerated transition to a warmer climate characterized by extreme temperatures and frequent heat waves, droughts, in some regions and heavy

Received 07 March 2014; accepted 27 March 2015. First Online: June, 2015. DII 2067-5720 RAR 2015-145

rainfall and storms, in others etc. (IPCC, 2007). Regularly, climate change scenarios point to the persistence and increased intensity of drought in critical agricultural regions of Europe (especially in the southern and south-eastern regions) as well as in Asia, Africa and North America, regions already vulnerable to water shortage, which trigger the decrease of the vegetation season for plants and the drop of agricultural production (Păltineanu et al., 2007a, 2009; Mitrică et al., 2013; Hov et al., 2013). At regional level, the studies undertaken so far stressed as major drivers of climate change in Romania the rise of air temperature, the reduction in annual precipitation amounts and ultimately, the intensification of extreme weather events, especially during the crop growing season (Marica and Busuioc, 2004; Păltineanu et al., 2007a, 2007b, 2009; Busuioc et al., 2010a; Sandu et al., 2010; Bălteanu et al., 2013).

The study area

The study-area is located in the south-western Romania, covering the southern part of the Banat – Crişana Plain, a component of the Pannonian Depression. Its surface expands over 739 km^2.

Timiş Plain is a densely populated region, which accounts for 346,818 inhabitants in 25 rural settlements and a city, with an average density of 341.7 inh./km^2. Timiş County (including Timiş Plain) also represents a driving force for the Romanian economy, the GDP coming third after that of Bucharest and of Ilfov County (Popa, 2006).

The particular natural features (climate, relief, hydrology etc.) as well as the political and socio-economical conditions turned Timiş Plain into one of the main economic regions of Romania. Additionally, due to its geographical position and the particularities of the main atmospheric circulation, the study-area displays a variety of climatic nuances specific for I 5 (warm dry) and II 6 (moderate sub-humid) agro-climatic regions, thus being characterized by a relative thermal and hydric stability in terms water shortage or water excess both under current climate conditions or future projected periods, thus being prone to the cultivation of cereal plants (mainly wheat and maize) (Figure 1).

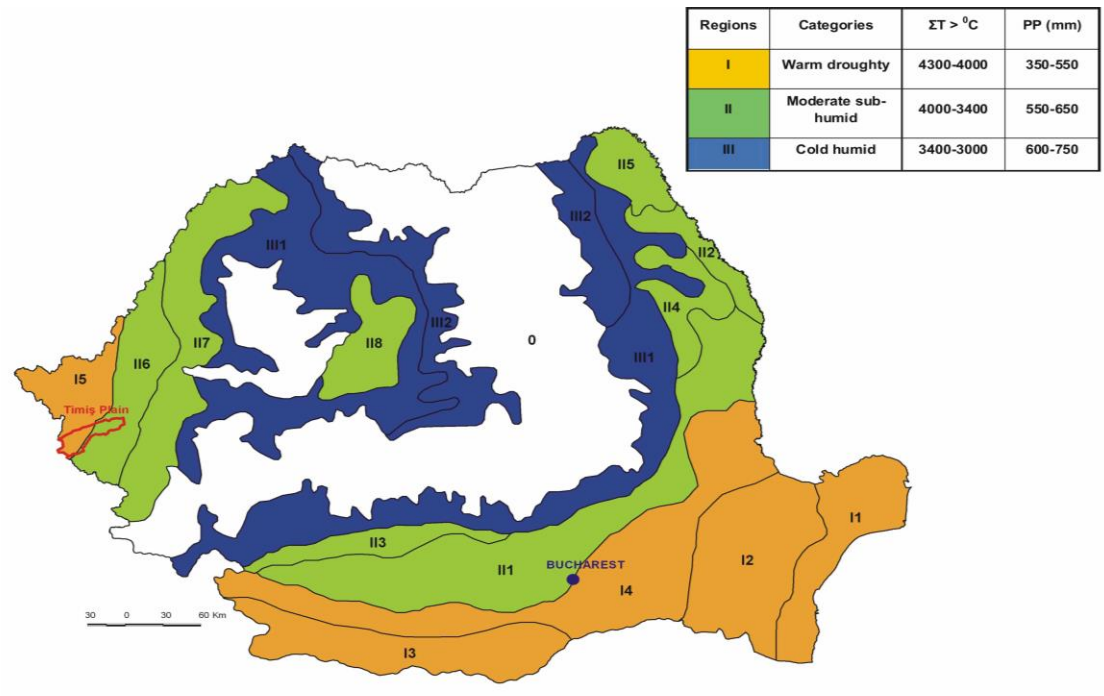

Figure 1. Framing Timiş Plain into the main agroclimatic regions of Romania
(processed after Neacşa and Berbecel, 1979; Sandu et al., 2010)

Also, this region has an important agricultural potential due to the natural conditions (relief, soils, climate etc.) which were propitious for expansion of agricultural land to over 80,0% of total surface area. Arable land represents around 85% from the agricultural land. Other land-use categories are represented by built-up areas which cover about 11.3% of the terrains and mostly include urban area (Timişoara city – 59.2% from total built-up surface), different buildings for agricultural and industrial activities, road and rail networks, etc. Forest vegetation cover relatively small surfaces (2.4%), because favourable natural conditions have in time led to the extension of farmland. These categories of lands are more extended in the central-eastern part of the study-area.

In 2011, most of the arable area was cultivated with grain cereals (wheat and rye 43.2% and maize 39.3% from the cultivated area), which are suggestive of a cereal-growing agriculture. Oleaginous plants (sunflower and rapeseed) covered 13.1% and other crops (potatoes, vegetables, fodder plants etc.) were grown only on 4.4% of the total cultivated area.

MATERIAL AND METHODS

The current study relies on observational data acquired from Timişoara agro-meteorological station, considered as the most significant for Timiş Plain. In order to assess the impact of climate change on maize and winter wheat crops the authors used two applications of CERES model: CERES-Wheat (Godwin et al., 1989) and CERES-Maize (Ritchie et al., 1989) under two regional climatic scenarios for 2021-2050 and 2071-2100 time frames.

1. Climate change scenarios for Timiş Plain

In Timiş Plain, changes in temperature and precipitation patterns over two future projected periods (2021-2050, 2071-2100) under A1B emission scenario, were acquired based on two sources (Busuioc et al., 2010a, 2012): statistical downscaling models developed against the reference period 1961-1990 and applied to the changes of predictors derived from two RCM simulations (CNRM and RegCM3) achieved in the framework of ENSEMBLES project (Van der Linden, 2009) and directly from 8 ENSEMBLES RCM outputs. As a result, one could reduce the uncertainties brought about by the differences of the climate change signals provided through various models. Consequently, among the 9 ENSEMBLES RCMs assessed by Busuioc et al. (2010a), the two RCMs considered as input in the SDMs are the most accurate in simulating the annual temperature and precipitation values for the study-area (Busuioc et al., 2010b; Mitrică et al., 2013).

2. Description of crop models and management variables

Generally, for the assessment of climate change-related impacts on agriculture, a variety of climate models are used. For their simulation the models require, besides multivariate weather series referring to current and future climate data, additional relevant information (biophysical, economic etc.). The authors used for the current study CERES (Crop-Environment Resource Synthesis) simulation model which was developed as a predictive and deterministic model (Tsuji et al., 1994). CERES was used for basic and applied research for the assessment of the effects of climate (thermal regime, water stress) and management (fertilization practices, irrigation) on the growth and yield of different agricultural crops. It can also be used for the evaluation of nitrogen fertilization practices on nitrogen uptake and nitrogen leaching from soil or, in global change research to assess the potential effects of climate change on rainfall and water use effectiveness due to CO_2 rise (Cuculeanu et al., 1999, 2002; Mateescu and Alexandru, 2010).

CERES model was developed in the framework of IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) project implemented in the DSSAT v3.5 (Decision Support System for Agrotechnology Transfer) developed by Tsuji et al., 1994 so as to become compatible with data inputs (climate, soil and crop) and precise simulation algorithms of the main processes of the crop pattern as well as statistical algorithms for biophysical, economic and strategic analysis (Tsuji et al., 1994). The model is aiming to simulate, over several years, the outcomes of different agricultural management practices as well as to assess and compare the results based on different input data (e.g. different management techniques under different climatic conditions for a specific crop). Accordingly, based on the interaction between the environmental factors and the biophysical characteristics of the crop, the effects of climate variability/change associated with crop performances can be measured (Mitrică et al., 2013).

For the current study, the authors used two applications of the CERES model in order to assess the impact of climate change on two of the most important agricultural crops in the Timiş Plain: maize and winter wheat crops. The models CERES-Wheat (Godwin et al., 1989) and CERES-Maize (Ritchie et al., 1989) referred to two regional climatic scenarios corresponding to 2021-2050 and 2071-2100 periods. These models measure, based on daily data, the main biophysical processes at the soil – plant – atmosphere interface under the variability of different physical and biological processes such as: specific phonological phases, photosynthesis, evapotranspiration, water dynamics in soil etc.

3. Database preparation and assessment of seasonal crop management

The data used for the growth and phenological development of the agricultural crops under discussion (winter wheat and maize) have been set up for the varieties whose genetic coefficients are representative for the average conditions of the 1961-1990 interval. These coefficients are much closer to the real phenological and production values registered on the standard platforms of the agro-meteorological station under discussion.

The winter wheat crop management variables taken as input data were obtained following the model calibration and validation. These data are differentiated in terms of the agro-climatic zone, particularly, the average sowing date (27 September – 29 October), average sowing density (450-650 plants/m^2), distance between rows (8-12.5 cm), and sowing depth (4-6 cm). For the maize crop, the sowing depth and the density were set according to current average conditions, namely April 3-28 for sowing and 35,000-50,000 plants/ha for density. All simulations were based on invariable average fertilization in which the nitrogen stress did not fall below 50% of the winter wheat and maize crops requirement (Mitrică et al., 2013).

In order to run the seasonal analysis programme integrated into the DSSAT v. 3.5 decision-making system, three elemental stages were unfolded: the elaboration of the seasonal experiment, the run of the simulation model for the crop types supported by the “driver” programme on seasonal analysis and biophysical analysis of simulated results. The soil data used were related to soil surface and the profile of the soil type, that is, the average hydrophysical characteristics of the specific soil types in the study-area: the clay, dust and sand content, the apparent density, organic carbon, pH, hydraulic conductivity etc.

Furthermore, to estimate the response of wheat and maize crops to the current climatic conditions, the real climatic data rows recorded at Timişoara weather station for the 1961-1990 period were used. As a result, the climatic data refer to the multi-annual and monthly mean values of the following parameters: minimum and maximum air temperature, the standard deviation of the minimum and maximum air temperature, precipitation amounts, standard deviation of precipitation, the asymmetry coefficient of the rainfall distribution, the probability of occurrence of a ‘dry’ day (without precipitation) after a ‘wet’ day (with precipitation), the probability for a “day” to follow a “wet” day, the number of days with precipitation and the solar radiation.

With the aim to assess the impacts of different climate scenarios on the agricultural crops under analysis, the two models were run bearing in mind the same farming management variables used for the current climatic conditions.

RESULTS AND DISCUSSION

Changes in the evolution of temperatures and precipitation under climate change predicted for the decades 2021-2050 (RCMs/2021-2050/SRES A1B) and 2071-2100 (RCMs/2071-2100/SRES A1B)

Generally, in accordance with the climate scenarios for the western part of Romania (Banat Plain), rather weak climate change signals are to be projected. The general outline of the climatic pattern of the study-area is triggered by the moderate thermal regime and excess rainfall mainly caused by the retrograde cyclones with south-west/north-east direction from the Gulf of Genoa to the centre and north-eastern Europe.

Therefore, against the current climatic period (1961-1990) value of 10.9°C, the mean annual temperature values are expected to decrease by 0.1°C for the 2021-2050 interval followed by a rise with 0.1°C during the 2071-2100 period.

The mean negative air temperatures are to be recorded only in January both under current (1961-1990) and future climate conditions (2021-2050 and 2071-2100). Against the values registered during the 1961-1990 timeframe, the thermal deviations expected to be reached during the 2071-2100 interval are superior to the ones of the 2021-2050 period. However, the highest monthly deviations for the two climate change projected periods are registered during May and June for the winter wheat (May and June/0.2 and 0.5°C, respectively) (Figure 2). For maize, the highest deviations are to be noticed in July and August for the same projected intervals (July/ 0.3 and 0.8°C, respectively and August/0.4°C and 0.9°C, respectively). At the same time, in September the mean monthly air temperature is estimated to increase with 0.3°C (2021-2050) and with 0.7°C (2071-2100) against the current climatic conditions.

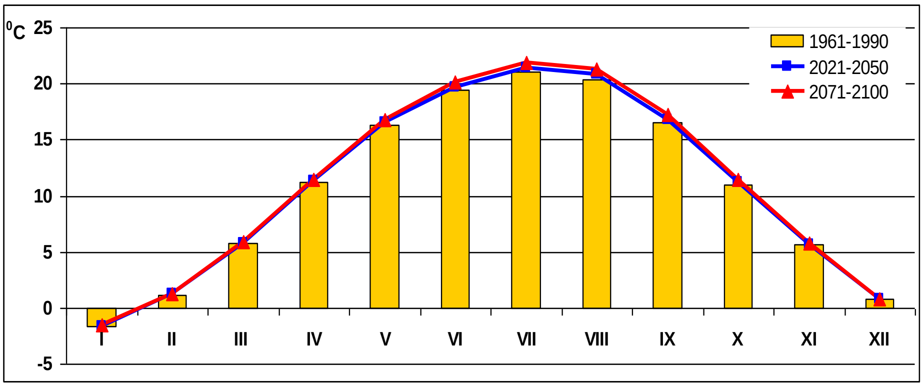

Figure 2. Mean monthly air temperatures under climate change conditions (2021-2050; 2071-2100) against the climatic reference period (1961-1990) at Timişoara weather station

On the whole, the monthly thermal differences in the Timiş Plain for the three analysed intervals are slightly diminished as compared to other regions located in the southern part of Romania, only for May – September period (relevant for the development of different key phenophases for crops). For the rest of the months, both the real and projected thermal values are balanced or show reduced variations.

On an annual basis, according to the climatic scenarios, the mean temperature values registers deviations of about 0.2°C for 2021-2050 and 0.5°C for 2071-2100 against the standard climatologic period mean temperature (10.6°C) (Figure 3).

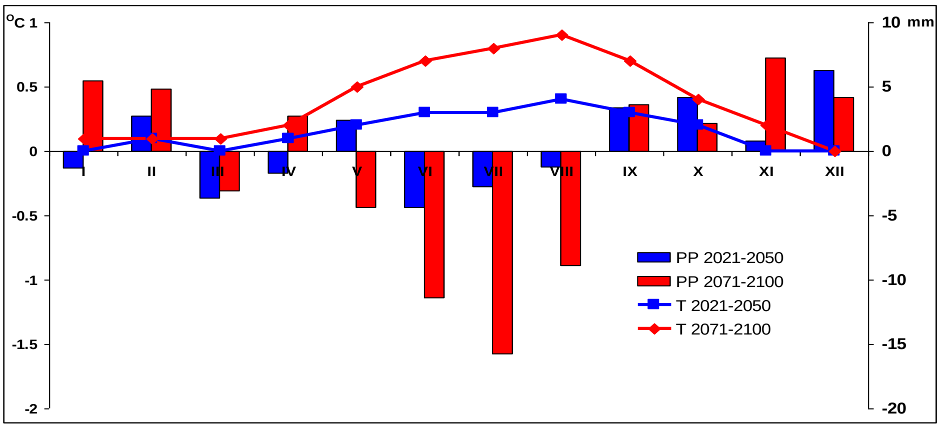

Figure 3. The variation of air temperature and precipitation during the two projected periods (2021-2050; 2071-2100) against the climatic reference period (1961-1990) at Timişoara weather station

In terms of *precipitation* amounts, in the study-area, throughout the two climate change projected intervals against the mean multiannual amounts registered during the reference period 1961-1990 (591.4 mm), one can notice a slight increase to 596.2 mm (2021-2050) followed by a moderate decrease of 578.2 mm (2071-2100), which means an overall decrease of only 13.1 mm characteristic for the second interval of climate change as compared to the first one. On an monthly basis, for the 2071-2100 time span, shrinks in March and May-August of up to -15.7 mm (August) are estimated. In the rest of the months, the rainfall amounts are positive, rising with up to 7.3 mm in November (Figure 4).

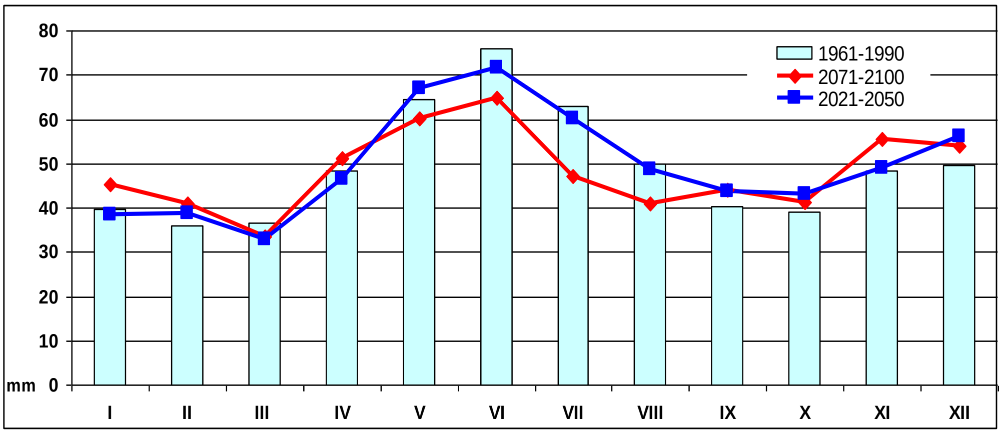

Figure 4. The variation of average monthly precipitation amounts (mm) under climate change conditions (2021-2050; 2071-2100) against the reference period (1961-1990) at Timişoara weather station

This annual deviation points to a quite reduced shrink, especially when considering a region not exposed to present and future water shortages and which, in terms of monthly precipitation amounts can be easily subject to moisture balancing throughout the year.

The impact of climate change on the main agricultural crops

Cultivated area and plant production were strongly influenced by the socio-economic and political conditions of the post-communist period. This influence depended on the farming practices (fewer natural and chemical fertilizers, poor mechanization), inadequate farm structure, agricultural policies etc., and besides, the intensification of climate change-induced extreme phenomena (drought, hail-storms, and floods), annually affecting ever larger cultivated areas. Over the last 20 years, the negative impact of these factors has been seen in very low average yields for the main crops (wheat, corn and sunflower) well below the productive potential of the region.

At Timişoara agro-meteorological station, the mean multiannual precipitation amounts are very similar to the optimal water requirements (601-650 mm/year) of winter wheat both on current (591.4 mm) and future climatic conditions for 2021-2050 (596.2 mm) and even for 2071-2100 (578.2 mm). Therefore, if the mean winter wheat yield under current climate conditions sums up to 4997 kg/ha, under expected future climatic periods it is expected to increase with 14.6% (2021-2050) and 20.0% (2071-2100) according to RCMs/SRES/A1B scenario. Moreover, the mean length of the vegetation period under the actual climatic conditions is of 271 days, while for the future climatic periods it is projected to shrank by 5 days (2021-2050) and 8 days (2071-2100) (Figure 5).

For maize crops, over the 2021-2050 timeframe, the required precipitation amounts during the vegetation period (April – October) are projected to register values similar to the current period (380 mm), while during the second analyzed period (2071-2100) values with about 8.9% lower (349 mm) are to be expected, especially in July (-25.1%). Furthermore, under the current conditions, the mean yield is of 5887 kg/ha, while, under the two climate change projected intervals a decrease with near 3.5% (2021-2050) and 15.7% (2071-2100) are to be expected. The shrank of maize yield is due to the shortening of the vegetation period with 5 (2021-2050) to 11 days (2071-2100) connected to temperature rise and increased water stress during the critical period for plants (heading and flowering), as a result of reducing the projected precipitation amounts for the June-August timeframe (Mitrică et al., 2013).

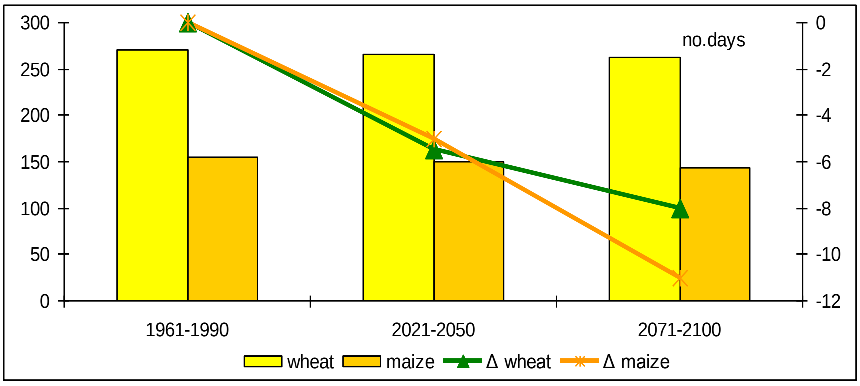

Figure 5. The vegetation period for winter wheat and maize for 1961-1990 period and their deviations under climate change conditions (2021-2050 and 2071-2100) at Timişoara weather station

When referring to the impact of potential climate change on crop production, these could vary depending on the genetic type of plants (C3 or C4), the direct effects of increased CO_2 on photosynthesis, local environment and the severity of the climatic changes induced by the two scenarios (Mateescu et al., 2010; Mitrică et al., 2013). Therefore, the maize yield would shrink in the future, especially in the case of RCMs/2071-2100 scenario (with 15.7%) due to rise of average air temperatures which determine a decrease of the vegetation period and the slight precipitation deficit for the June – August period, especially during the maximum development phase for this crop.

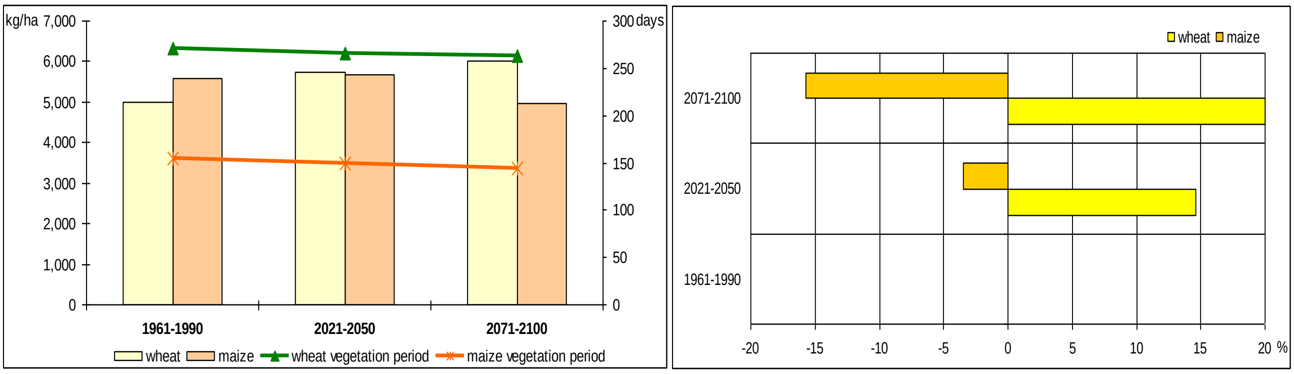

Figure 6. Winter wheat and maize production in relation to the vegetation period (A) and their share dynamics (B) under climate change (2021-2050; 2071-2100) against the reference period (1961-1990) at Timişoara weather station

In case of winter wheat, under the two analysed climatic scenarios, the production will grow with about 14.6% for the 2021-2050 period and 20.0% during the 2071-2100 interval, due to the positive effect of rising atmospheric concentrations of carbon dioxide (CO_2) from 330 ppm (1961-1990) to 450 ppm (2021-2050) and 550 ppm (2071-2100) on photosynthesis and water use, which counteract the negative effect of shortening the vegetation period.

CONCLUSIONS

The assessment of the complex relationships between climate change and agricultural productivity in the Timiş Plain emphasized their potential impacts on the main agricultural crops (winter wheat and maize) under two selected regional climatic scenarios.

Therefore, the climate change signals stresses upon significant effects on crops depending on some stressors such as: the interaction between local climatic conditions, the estimated climatic parameters, the effect of rising CO_2 on photosynthesis and the genetic type of agricultural crops.

The winter wheat benefits from the interaction between the rise of CO_2 and air temperature while maize is more vulnerable to climate change, especially hot and dry RCMs/2071-2100/SRES A1B scenario. Under the same climate change conditions, the maize yield might be subject to shrinkage, more severe in the case of RCMs/2071-2100 scenario due to temperature raise which trigger shortening of the vegetation period coupled with water stress, especially during the flowering and yield formation interval (June – August).

Hence, the temperature rise foreseen by both climate change scenarios triggers a decrease of the vegetation period. Therefore, up to the end of the century (2071-2100), the growing season for both crops would end much earlier as compared to the reference period or even the 2021-2050 interval. Under these conditions, the rising of atmospheric concentrations of carbon dioxide (CO_2) during the two climate change projected intervals (2021-2050 and 2071-2100) will have a positive effect on photosynthesis, which might lead to increase yields, which counteract the negative effect of shortening the vegetation period.

In general, considering the framing of Timiş Plain into the warm dry and moderate sub-humid agro-climatic regions with the associated climatic particularities, severe water deficits for agricultural crops are likely to be experienced during either current period or future projected periods.

Acknowledgements

The research for this paper was performed within the Institute of Geography’s research plan (the priority research project of the Romanian Academy on “Geographical Study of the Romanian Danube Valley”) as well as within the project funded by South East European Programme (SEE) on “Climate Change and Impacts on Water Supply” (CC-WaterS), 2009-2012.

REFERENCES

Bălteanu, Dan, Dragotă, Carmen-Sofia, Popovici, Ana, Dumitraşcu, Monica, Kucsicsa, Gheorghe, Grigorescu, Ines, 2013. *Land use and crop dynamics related to climate change signals during the post-communist period in the South Oltenia, Romania*. Proc. Rom. Acad., Series B, 15, 3: 265-278.

Busuioc, A., Caian, M., Cheval, S., Bojariu, R., Boroneanţ, C., Baciu, M., Dumitrescu, Al., 2010a. *Variabilitatea şi schimbarea climei în România.* Editura PRO Universitaria, Bucureşti, 226 p.

Busuioc, A., Dumitrescu, A., Baciu, M., Cazacioc, L., Cheval, S., 2010b. *RCM performance in reproducing temperature and precipitation regime in Romania. Application for Banat and Oltenia Plains*. Romanian Journal of Meteorology, 10, 2.

Busuioc, A., Dumitrescu, A., Baciu, M., Cazacioc, L., 2012. *Uncertainties in downscaling of Global Climate Change scenarios. Comparison between dynamical and statistical techniques.* European Geosciences Union General Assembly 2012, Vienna, Austria, 22-27 April, 2012.

Busuioc, A., Dumitrescu, A., Baciu, M., Cazacioc, L., Cheval, S., 2011. *Changes in climate regime of Banat and Oltenia Plains and associated uncertainties*, http://www.ccwaters.eu/index.php

Cuculeanu, V., Marica, A., Simota, S., 1999. *Climate change impact on agricultural crops and adaptation options in Romania.* Climate Research, 12: 153-160.

Cuculeanu, V., Tuinea, P., Balteanu, D., 2002. *Climate change impacts in Romania. Vulnerability and adaptation options.* GeoJournal 57: 203-209, Kluwer Academic Publishers. Printed in the Netherlands.

Entwisle, B. and Stern, P.C. (eds.), 2005. *Population, Land Use, and Environment: Research Directions.* National Research Council (US) Panel on New Research on Population and the Environment, National Academies Press, Washington DC., 330 p.

Godwin, D.C., Ritchie, J.T., Singh, U., Hunt, L., 1989. *A user’s guide to CERES-Wheat: v2.10.* International Fertilizer Development Center, Muscle Shoals, AL.

Hov, O., Cubasch, U., Fischer, E., Höppe, P., Iversen, T., Kvamsto, N.G., Kundzewicz, Z., Rezacova, Daniela, Rios, D., Duarte Santos, F., Schädler, B., Veisz, O., Zerefos, C., Benestad, R., Murlis, J., Donat, M., Leckebusch, G.C., Ulbrich, U., 2013. *Extreme Weather Events in Europe: preparing for climate change adaptation*. Norwegian Meteorological Institute, The Norwegian Academy of Science and Letters, 140 p.

IPCC, 2007. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignorand, M., Miller, H.L. (Eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Koeck, R. (ed.), 2012. *Climate Change and Impacts on Water Supply.* "CC-WaterS" Retrieved from http://www.ccwaters.eu/downloads/CC WaterS_Project_Monography_final.pdf

Marica, A., Busuioc, A., 2004. *The potential of climate change on the main components of water balance relating to maize crop*. Roumanian Journal of Meteorology, 6, 1-2: 40-49, Bucharest, Romania.

Mateescu, E., Alexandru, D., 2010. *Management recommendation and options to improve crop systems and yields on south-east Romania in the context of regional climate change scenarios over 2020-2050.* UASVM Bucharest, Series A, Vol. LIII: 328-334. ISSN 1222-5339

Mitrică, Bianca, Mateescu, Elena, Dragotă, Carmen-Sofia, Busuioc, Aristiţa, Grigorescu, Ines, Popovici Ana, 2013. *Climate change impacts on agricultural crops in the Oltenia Plain (Romania).* The 13th International Multidisciplinary Scientific GeoConference SGEM, 16-22 iunie, 2013, Albena, Bulgaria, Energy and Clean Technologies Conference Proceedings. Section Air Pollution and Climate Change: 573-584.

Neacşa, O., Berbecel, O., 1979. *Climatologie şi agrometeorologie*. Editura Didactică şi Pedagogică, Bucureşti.

Nelson, G.C, Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, Claudia, Msangi, S., Palazzo, Amanda, Batka, M., Magalhaes, Marilia, Valmonte-Santos, Rowena, Ewing, Mandy and Lee, D., 2009. *Climate Change Impact on Agriculture and Costs of Adaptation.* International Food Policy Research Institute, Food Policy Report, Washington, 30 p. DOI: 10.2499/0896295354

Păltineanu, Cr., Mihăilescu, I.F., Prefac, Z., Dragotă, C.S., Vasenciuc, F., Nicola, C., 2009. *Combining the standardised precipitation index and climatic water deficit in characterising droughts: a case study in Romania*. Theoretical and Applied Climatology, Springer Verlag Vienna, 97: 219-233.

Păltineanu, Cr., Mihăilescu, I.F., Seceleanu, I., Dragotă, C.S., Vasenciuc, F., 2007b. *Using aridity indexes to describe some climate and soil features in Eastern Europe: a Romanian case study*. Theoretical and Applied Climatology, Springer Verlag Vienna, 90: 263-274.

Păltineanu, Cr., Mihălescu, I.F., Seceleanu, I., Dragotă, Carmen-Sofia, Vasenciuc, F., 2007a. *Ariditatea, seceta, evapotranspiraţia şi cerinţele de apă ale culturilor agricole în România*. Editura Ovidius University Press, 319 p., Constanţa.

Popa, N., 2006. *Frontiere, regiuni transfrontaliere şi dezvoltare regională în Europa Mediană.* Editura Universităţii de Vest, Timişoara.

Ritchie, J.T., Singh, U., Godwin, D.C., Hunt, L., 1989. *A user's guideto CERES-maize*: *v2.10.* International Fertilizer Development Center, Muscle Shoals, AL.

Sandu, I., Mateescu, E., Vătămanu, V., 2010. *Schimbări climatice în România şi efectele asupra agriculturii.* Editura SITECH, Craiova.

Tsuji, G.I., Uehara, G., Balas, S. (Eds.), 1994. *DSSAT v3.0*. Vols 1, 2 and 3, University of Hawaii, Honolulu.

Van der Linden, P. and Mitchel, J.F.B. (Eds.), 2009. *ENSEMBLES: Climate Change and its Impacts: Summary of research and results from the ENSEMBLES project*. Met. Office Hadley Centre, FitzRoy Road, Exeter EX1 3PB, UK. 160 pp.