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CHARACTERISTICS OF EXTREME TEMPERATURES RELEVANT FOR AGRICULTURE IN THE NEAR FUTURE (2021-2040) IN ROMANIA

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Abstract

Extreme temperature episodes may have a significant impact on agriculture, as temperature is a primary factor affecting the rate of plant development. In Romania, agriculture is an important contributor to PIB and up to 19% of active population is employed in this sector. Therefore, assessing the changes in the thermal regime and its extremes in the near future may contribute to a sounder approach for developing and implementing adaptation measures in agriculture. In this view, we investigate the changes in the extreme temperature's characteristics in Romania for the near future (2021-2040) by making use of climate projections of maximum and minimum temperature in the context of two climate change scenarios. We employ a series of climate indices focusing on high/low temperatures, selected from the INDECIS project indices database (www.indecis.eu), which are used to highlight the change in extreme temperatures occurrence compared to the base (reference) period 1991-2010. The results are presented for the entire territory, also discussing the uncertainties associated with the methodological aspects.

***Key words**: agriculture, climate change, extreme temperature, Romania.*

INTRODUCTION

Agriculture is an important economic sector in Romania, with a contribution to GDP of 4-6%, compared with an average of 1.7% at UE level in 2015 (MADR, 2015) and about 19% of population formally employed (EC, 2020). Considering its significant dependence on weather and climate, the long-term planning in this sector may benefit from insights on possible evolutions of specific climate conditions, based on available climate scenarios.

Studies on the temporal evolution of some parameters in the current climate over Romania showed an increasing tendency of air temperature and related parameters.

Dumitrescu et al. (2014) shows that over 1961-2013 period the annual thermal extremes present decreasing trends for the cold-related indices and increasing trends for the warm-related ones, with the warming signal being consistent over the region. The same is valid for the Carpathian region, as shown by (Birsan et al., 2014).

Busuioc et al. (2014) highlighted that during period 1961-2010 significant increasing trends for the temperature extremes are detected in all seasons, except for autumn, with the highest increasing rate in summer and the lowest in spring. Furthermore, other studies more oriented toward agriculture (ORIENTGATE, 2014; Sima et al., 2015; Colan et al., 2019; Şmuleac et al., 2020) showed increasing trends for some thermal indices relevant for agriculture. In this context, assessing the changes in the thermal regime and its extremes in the near future may contribute to a sounder approach for developing and implementing adaptation measures in agriculture.

To this end, our study focuses on the changes in the extreme temperatures over Romania in the near future (2021-2040) in the context of two climate change scenarios by using thermal indices related to low/high temperatures relevant for agriculture sector.

MATERIALS AND METHODS

The analysis presented in this study focuses on the near-future period (2021-2040), highlighting the changes in 6 thermal indices by comparison with the base (reference) period 1991-2010.

For the climate projection data, we employ bias-adjusted daily time series of minimum and maximum temperature from an ensemble of Regional Climate Models (RCMs) from EURO-CORDEX, available from https://data.jrc.ec.europa.eu/dataset/jrc-liscoast-10011. The data are run over a numerical domain covering the European continent at a resolution of 0.11°. Historical runs, forced by observed natural and anthropogenic atmospheric composition, cover the period from 1950 to 2005; the projections (2006-2100) are forced by two Representative Concentration Pathways (RCP), namely, RCP4.5 and RCP8.5. RCMs' outputs have been bias-adjusted using the methodology described in e.g. (Dosio and Paruolo, 2011) using the observational data set EOBSv10, and applied to the EURO-CORDEX data by (Dosio, 2016) and (Dosio and Fischer, 2018).

From the 11 simulations available within this dataset (Table 1), we employed 2 simulations (marked in bold in Table 1).

Table 1. Climate projection simulations available from http://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/LISCOAST/10011/LATEST/EURO-CORDEX/EUR-11/

Regional model	**Driving model**
CCLM-4-8-17	**CNRM-CEFACS-CNRM-CM5**
	MPI-M-MPI-ESM-LR
	ICHEC-EC-EARTH
DMI_HIRHAM	ICHEC-EC-EARTH
IPSL-INERIS-WRF331F	IPSL-IPSL-CM5A-MR
KNMI-RACMO22E	ICHEC-EC-EARTH
SMHI-RCA4	CNRM-CEFACS-CNRM-CM5
	ICHEC-EC-EARTH
	IPSL-IPSL-CM5A-MR
	MOHC-HadGEM2-ES
	MPI-M-MPI_ESM-LR

To select these, we firstly identify the models simulations leading to the lowest changes in the mean temperature at country level, for RCP45 scenario and respectively to the highest change in the mean temperature averaged over the entire country in the context of RCP85 climate change scenario compared to the BASE period (1991-2010) (Figure 1). The selection method allows highlighting the range of change in the indices considered, taking into account the uncertainties associated with the numerical climate models, both at large scale and on limited areas, as well as the uncertainties associated with climate changes, by employing two scenarios.

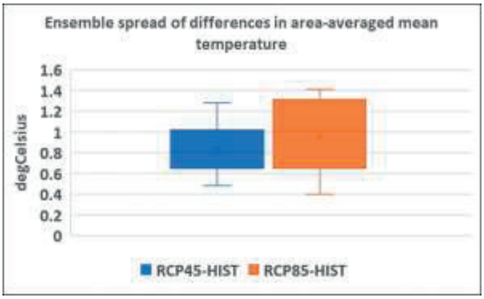

Figure 1. Ensemble spread of differences in the mean temperature area-averaged over the Romanian territory, for 11 climate projection simulations for the periods 1991-2010 (BASE) and 2021-2040 (RCP45, RCP85)

For the next step, we used projections of minimum and maximum temperatures (T_{min} and T_{max}) from each of the selected simulations, to compute six thermal indices, for BASE and near-future periods, for each climate change scenario. The indices are selected from INDECIS project database of indices (http://www.indecis.eu/indices.php) and they are defined as follows:

- **NTN** - Minimum value of monthly maximum air temperature (Klein et al, 2009);
- **FD** - number of frost days (when $T_{min} < 0°C$) (Klein et al, 2009);
- **STN10** - sums of minimum air temperatures below -10°C recorded in December-February interval (Sandu et al, 2010);
- **XTX** - Maximum value of monthly maximum air temperature (Klein et al, 2009);
- **ID** - Number of days with $T_{max} < 0°C$ (ice days);
- **STX32** - Temperature sums above 32°C (June-Aug) (Sandu et al., 2010).

The results are presented in terms of spatial distribution of absolute differences between climate projections and the associated BASE simulations (denoted as RCP45-BASE and

RCP85-BASE, respectively). Also, we present the results for BASE period corresponding to each selected simulation, for each index.

RESULTS AND DISCUSSIONS

The indices derived from minimum temperature for the BASE period from the two selected simulations are presented in Figure 2. The mountainous regions show the lower values of monthly minimum temperature (-10°C up to -8°C) as well as the largest values of frost days (150 ÷ 170 days/year) and sums of temperatures
below the threshold of -10ºC (between 600 and 1000°C), followed by the extra-Carpathian regions. The western, southern and eastern areas have, as expected, higher temperatures as seen through higher values of minimum monthly temperatures (-3°C ÷ -0°C), a smaller number of frost days (90 ÷ 120 days) and lower values of STN10 index.

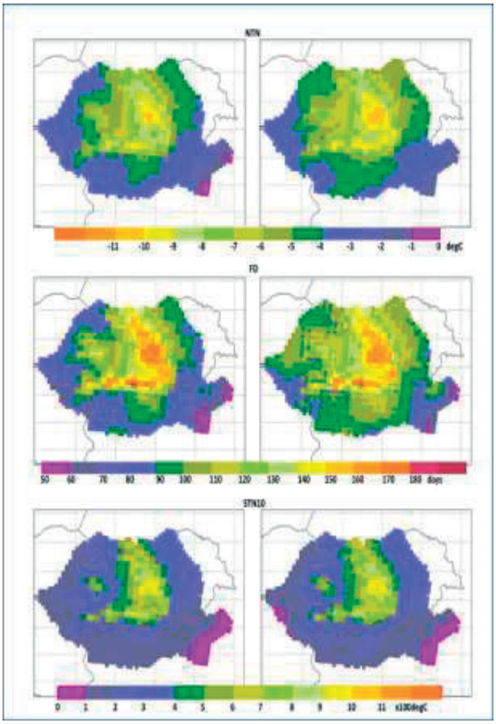

Figure 2. Spatial distribution of the indices based on minimum temperature (NTN, FD, STN10), for BASE period (1991-2010) for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column)

It is worth noting that the two simulations, although in general agreement with regard to spatial pattern, present some differences too, related to smaller values of minimum temperatures in some regions like Eastern Carpathians, southern and eastern areas. These differences are more likely due to the ability of the regional climate model in simulating the observed temperature regime. These differences do not affect the overall analysis, as the expected changes of the indices are assessed by comparison of the climate projections with the BASE period provided by the same combination of large scale and regional climate models. Nevertheless, they are important for understanding the characteristics of the tools used (i.e. numerical models) and for properly addressing the uncertainties associated with them.

The change of indices related to the minimum temperature in the context of climate changes is shown in Figure 3. In general, the minimum monthly temperature (NTN) is expected to rise in both scenarios compared to BASE period. However, for the RCP45 scenario and in particular for the south-western region, the two scenarios indicate divergent evolutions of the minimum temperature- a light decrease in the RCP45 scenario (-0.5°C) and increase in the RCP85 scenario (1.5°C ÷ 2.5°C). For the rest of the territory, the increasing tendency is visible in both scenarios, but more pronounced in RCP85 scenario. The most affected regions in this latter case are in the Eastern Carpathians and Apuseni Mountains (up to 3.5°C), followed by western, southern and eastern sectors, with an increase of 2÷2.5°C.

The mixed signal between the RCP45 and RCP85 scenarios is visible in the other two indices too. In the RCP45 scenario, an increase in the number of frost days is visible for southern, western and Eastern Carpathians (5-10 additional days), while the RCP85 scenario suggests a sizeable decrease of about 10-15 days less in southern, eastern and western regions and more than 5 days less in the hilly and mountainous regions. Similarly, the sum of degrees below -10ºC is expected to increase in the RCP45 scenario in almost the entire country with about 25% compared to the BASE period, while in the RCP85 scenario the STN10 index presents lower values in the entire country except for some small areas in the western and eastern parts. The differences between the results of the climate projections for the near-future are more pronounced for the indices looking at extreme cases (frost days, STN10) than at the mean values (i.e. NTN) and they are most likely related to the uncertainties associated with the climate change scenarios.

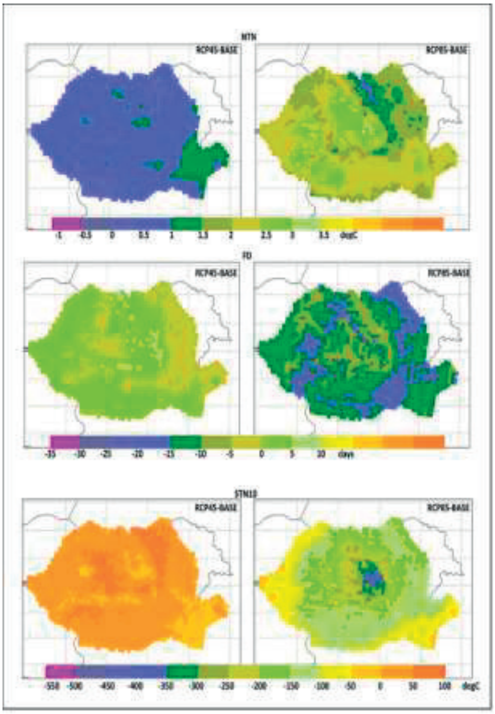

Figure 3. Spatial distribution of the change in the indices based on minimum temperature (NTN, FD, STN10), for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column) compared to the BASE period (1991-2010)

For the indices derived from the maximum temperature the spatial distribution for the BASE period in the two climate change scenarios are shown in Figure 4.

Just as the in the case of indices based on minimum temperatures, there are some differences between the two sets of results, the regional climate model associated with the RCP85 scenario indicating slightly larger maximum temperatures (up to 1°C) on limited areas in the western, southern and eastern regions. Yet, this translates only in a smaller degree in the values of the other two indices. More specifically, the number of days with maximum temperature below 0°C is in general lower based on the regional climate model associated with the RCP45 scenario and, also in this case, the sum of temperatures above 32°C is larger, on limited areas, than in the model associated with RCP85 scenario. This suggests that the two models present a lower agreement with regard to the simulation of current climate in terms of extreme (low/high) temperature, the model associated with RCP45 scenario leading to higher positive temperatures.

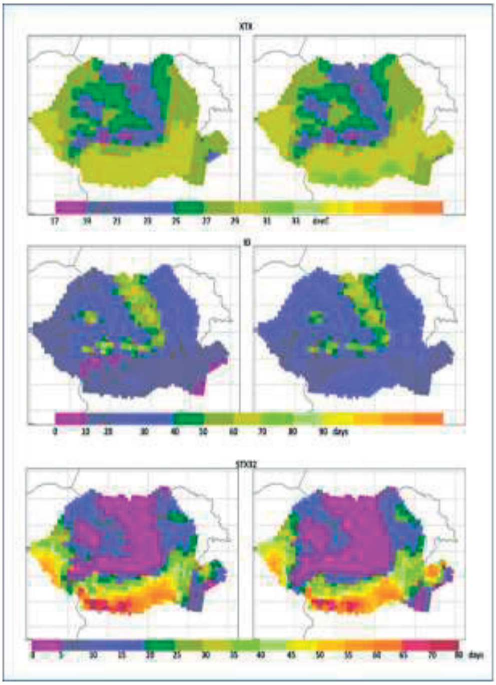

Figure 4. Spatial distribution of the indices based on maximum temperature (XTX, ID, STX32), for BASE period (1991-2010) for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column)

The changes for the near-future period in the indices derived from maximum temperatures in the context of climate changes are presented in Figure 5.

The maximum monthly temperature is expected to increase in both scenarios over the entire country, the amplitude of the increase being slightly larger in the RCP85 scenario (up to 0.5°C). This is further translated, in the RCP85 scenario, into a smaller number of ice days (around 10-15 days less in the high mountainous regions and up to 5 days less in the western, southern and eastern areas) and in a larger value of STX32 index especially in the south and eastern regions, compared to the RCP45 scenario. It is worth noting that the number of ice days may also increase, in the RCP45 scenario, with up to 5 days in the western, southern and eastern areas.

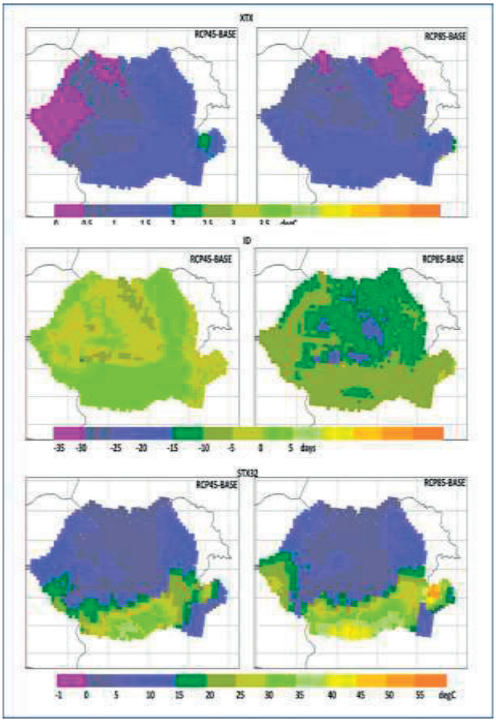

Figure 5. Spatial distribution of the indices based on maximum temperature (XTX, ID, STX32), for simulations corresponding to RCP45 scenario (left column) and RCP85 scenario (right column) compared to the BASE period (1991-2010)

CONCLUSIONS

We presented an analysis of the changes in six indices related to extreme low and high temperatures, relevant for agriculture, for the near-future period (2021-2040) in the context of two climate change scenarios.

The results suggest that both minimum and maximum monthly temperature may increase in the near future, more pronounced in the context of RCP85 scenario, the most affected regions being the Eastern Carpathians and Danube Delta. For the indices related to low values of temperatures, based on either minimum or maximum temperature (i.e. FD, STN10, ID) the selected climate projections present mixed signals: in the context of RCP45 scenario these indices present an increasing tendency on some limited areas in western, southern and eastern regions, while the RCP85 scenario suggest a decrease of their value over the entire country. The change in the regime of high temperature, expressed through the STX32 index, presents a clear positive tendency in both scenarios, more pronounced in the RCP85 scenario, especially in the southern and eastern areas.

The results contain the limits related to the data and method used. The climate projection data is affected by several sources of uncertainty, the most important being associated with the limitations of numerical models in simulating the climate system, with the climate change scenarios, but also with the natural variability of the climate system. This is already visible in the results presented, for example in the differences between the spatial distribution pattern of indices for the BASE period as derived from the two selected combinations of large scale and regional climate models or in the mixed signal for the projected changes of indices related to low temperatures. The method used addresses these sources of uncertainty (e.g. by employing more than once climate change scenario). By employing two model simulations which describe ‘extreme’ instances of possible evolution of climate in the near future, in terms of change of mean temperature at country level, based on a set of 11 simulations, our approach fits the aim of the study and it is tailored for the specific region of Romania. Nevertheless, it is possible that a higher level of confidence may be obtain by using more model simulations. Furthermore, selecting the indices such that to be more specific (e.g. with thresholds for specific cultivated plants) would bring significant added value for developing efficient adaptation measures in agriculture.

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