TEMPERATURE-BASED CLIMATE INDICATORS RELEVANT FOR AGRICULTURE SECTOR IN THE CONTEXT OF CLIMATE CHANGES IN OLTENIA

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ABSTRACT

We present an analysis of changes of several thermal-based climate indicators relevant for agriculture in the context of climate changes for the near-future (2021-2040), aiming to highlight the extremes of these changes. To this end, we use bias-corrected results of climate projections performed with 5 regional climate models in the context of RCP45 and RCP85 scenarios at European scale, available from Joint Research Centre (https://data.jrc.ec.europa.eu/dataset/jrc-liscoast-10011). We firstly identify the models' simulations which lead to the lowest increase in the mean air temperature at national scale in the context of RCP45 scenario and respectively to the highest increase, in the RCP85 scenario. We further use these instances to estimate the changes in 5 temperature-based indicators which are relevant for the agriculture sector. The indices characterize the bounding seasons (i.e. heating degree days) or are more specifically oriented for the growing season (i.e. Growing degree days; Winkler index).

The target area is Oltenia, a region situated in the SW of the country and an important agricultural basin, which is analyzed in the context of changes over the entire territory. The results may provide additional elements for further studies focusing on the impact of climate change and adaptation solutions in this region.

INTRODUCTION

Agriculture is one of the human activities most directly related to weather and climate and thus prone to significant impact due to climate changes. In Romania, 62% of country area is used for agriculture, about 19% of population being formally employed (with salaries) in this sector (EC, 2020). In Oltenia – the region in SW of the country- a similar situation is found, with 54% of population living in rural area (at 1 January 2019), agriculture accounting for 30% of the total (formal) employment (National Institute for Statistics). The SW Oltenia development region has a high potential for agriculture; between 2005-2012, it ranked second in the country regarding the orchard and fruit tree nurseries cultivated areas; there are big areas cultivated with energy plants, especially in the Dolj and Olt counties, which gives the region a high interest in smart specialisation for agriculture (EC, 2019).

These aspects highlight both the potential opportunities but also the vulnerability of the region to modification of climate conditions relevant for agriculture, in the context of climate changes. The investigation of physical impact of climate changes targeting the agriculture sector may provide the basis for an informed decision-making process at all levels as well as for planning and implementing adaptation measures.

We present in this study an assessment of the physical impacts of climate changes in agriculture sector in Romania, quantified with the use of five thermal indices, for the near-future period (2021-2040).

MATERIALS AND METHODS

In order to investigate the changes in climate conditions for agriculture sector during near-future period, we employ bias-corrected results of 11 climate projections performed with 5 regional and 5 global climate models in the context of RCP45 and RCP85 scenarios at European scale, based on EURO-CORDEX experiment, available from Joint Research Centre (https://data.jrc.ec.europa.eu/dataset/jrc-liscoast-10011). We identify the models simulations which lead to the lowest increase in the mean air temperature averaged over the entire Romanian territory in the context of RCP45 scenario and respectively to the highest increase, in the RCP85 scenario (Fig. 1). The selection of the simulations accounts for the uncertainties associated with numerical climate models (both large-scale and regional models) by choosing different regional climate models driven by different large-scale models. It also accounts for the uncertainties associated with the climate change scenarios by employing simulations for two different scenarios (RCP45 and RCP85). Furthermore, since we are interested in extreme changes, the selection method assures that the selected simulations are representative for the study area and for the objectives of the study.

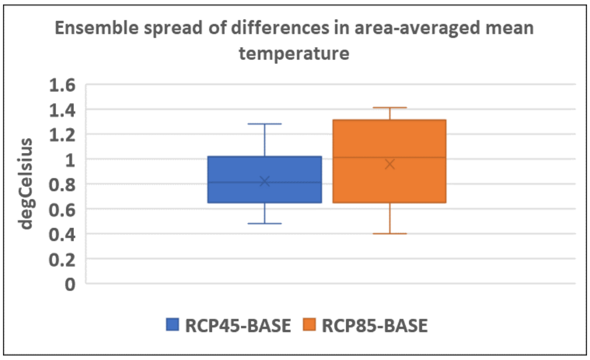

Figure 1. Ensemble spread of differences in the mean temperature area-averaged over the Romanian territory, for 11 climate projection simulations for the periods 1991-2010 (BASE) and 2011-2040 (RCP45, RCP85).

The analysis makes use of five thermal indices relevant for the agriculture sector, based on mean daily temperature, namely:

- HD17 - the heating degree days index (Klein et al, 2009) is defined as the sum of temperatures below 17 °C along a year.

- GD4 - growing degree days (Klein et al, 2009) - represents the sum of temperatures exceeding 4 °C over one year.

-TAO - Growing-season temperature from April to October (Klein et al, 2009) - is defined as the average daily temperature in the interval 1 April - 31 October.

-TMS - growing-season temperature from May to September (Klein et al, 2009) – represents the average daily temperature during the interval 1May -30 September.

-WKI – the Winkler Index (Winkler et al, 1974) is defined as the sum of degrees exceeding 10 °C during 1 April- 31 October.

These indices are also employed by INDECIS project (*Integrated approach for the development across Europe of user oriented climate indicators for GFCS high-priority sectors: agriculture, disaster risk reduction, energy, health, water and tourism*) (www.indecis.eu) where they are computed from ECA&D

database over the entire Europe, at a spatial resolution of 25 km, and they are freely available on project website (http://www.indecis.eu/indices.php). Also, they have been employed to characterize the thermal regime in Oltenia in the current climate (Colan et al, 2020).

The analysis focuses on changes of the indices during period 2021-2040 compared with base (reference) period (1991-2010). The indices are computed for each model, in each scenario, for the base and future periods. The results for the reference period, for each pair of models (numerical experiments) are compared with the spatial distribution of each index derived from ROCADA dataset (Dumitrescu and Birsan, 2015), which is used as reference observation data. The changes in the index values, shown as spatial distribution, are expressed as the relative difference between near-future and base period, in order to account for the model biases as well as for the uncertainties associated with the forcing data. The characteristics of Oltenia region are highlighted in this context.

RESEARCH RESULTS

The spatial distribution of HD17 long-term mean values over the entire territory (Fig.2) shows, for the reference observation data (ROCADA), the lowest values in western, southern and south-eastern regions, as expected based on the climatological distribution of temperature which indicates these regions as having the largest annual temperatures (Administratia Nationala de Meteorologie, 2008). Oltenia region, situated in the W-SW part of the country, is characterized by HD17 mean values of 2500-3000 °C, larger during the analyzed period (1991-2010) compared to the climatological standard period (1981-2010) (Colan et al, 2020). The model simulation for the same period (Fig.2, upper right) shows a similar spatial pattern but with lower values, in particular in the southern part of the country and in the mountainous areas, indicating for Oltenia region a HD17 index of about 2000-2500 °C.

It should be noted that Figure 2 shows the simulation for the base period realized with the model used in the selected RCP45 scenario simulation. Although for RCP85 scenario another model was used, the results from both models for the base period are very similar for all indices and thus only one simulation is presented for the base period for each index.

The relative change of HD17 index in the ‘colder’ RCP45 case (i.e. associated with lowest increase of area-averaged mean daily temperature at national scale) shows a low magnitude – in the range [-4,-2] % - compared with the reference period. The warmer case (RCP85 scenario) suggests a stronger decrease over the entire territory, most pronounced in the coastal area (-18%) and southern and north-eastern regions (-14% to -12 %). The reduction of the HD17 index values is a direct consequence of the increase in daily mean temperature associated with climate changes.

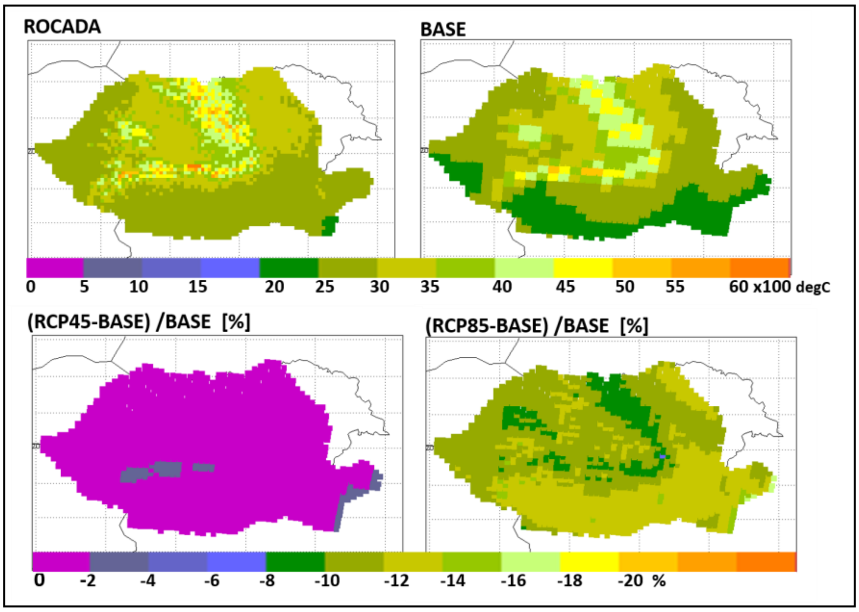

Figure 2. HD17 index: Distribution of long-term mean values (1991-2010) from ROCADA (upper left) and model simulation (BASE) (upper right); relative change in HD17 index during period 2021-2040, compared to 1991-2010, in the context of RCP45 scenario (lower left) and RCP85 scenario (lower right).

The GD4 index derived from the reference dataset ROCADA (Fig. 3, upper left) shows the largest values in the southernmost areas (3500°C), followed by values around 3000 °C in the hilly areas in Oltenia as well as in the western and eastern regions. The lowest values are found in the mountains and intra-mountainous areas (1000°C). The model simulation is in good agreement with the reference data.

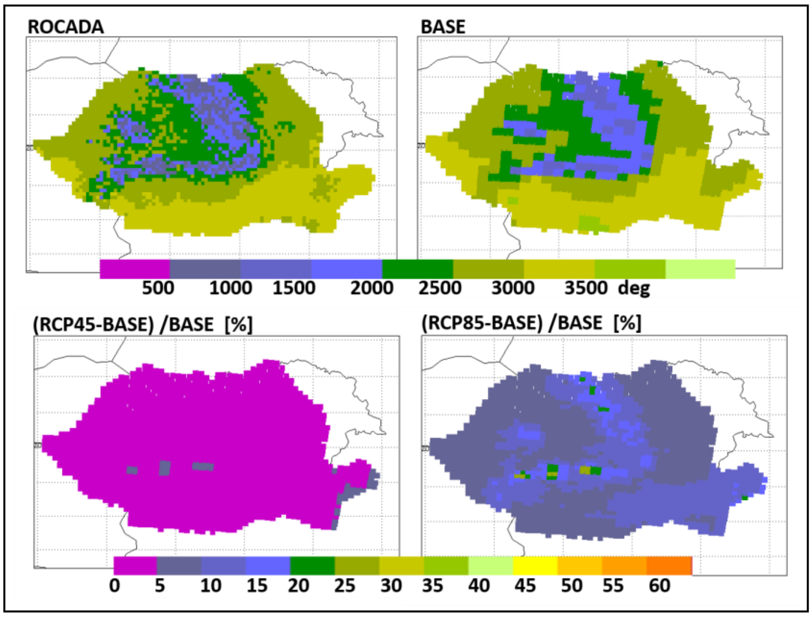

Figure 3. GD4 index: Distribution of long-term mean values (1991-2010) from ROCADA (upper left) and model simulation (HIST) (upper right); relative change GD4 index during period 2021-2040, compared to 1991-2010, in the context of RCP45 scenario (lower left) and RCP85 scenario (lower right).

The changes in GD4 index in both scenarios indicate an increase over the entire territory. While the colder scenario shows an almost negligible increase (up to 5%) in almost the entire country, in the context of warmer scenario the amplitude of the increase is differentiated spatially, showing GD4 values larger with up to 20% in the Baragan plain and mountainous areas. In Oltenia, the relative increase in GD4 index compared to the reference period is about 10%. The growing season temperature indices TAO and TMS present similar patterns based on reference data (Fig 4 and 5), characterized by larger values in the south, followed by western and eastern areas. In Oltenia region, TAO derived from reference data indicates long-term mean values in the range 16-18 °C. However, the model simulation for the base period shows slightly larger values (up to 2°C larger) over the entire territory, in Oltenia indicating TAO values of about 21 °C. Likewise, the distribution of TMS index presents maximum values of 18-20 °C in the southernmost areas and values in the range 16-18 °C in the rest of the southern region, the model simulation showing larger values over the entire territory.

The relative changes in TAO index is quite small (below 5%) in the context of 'colder' scenario (RCP45), over the entire territory, with the exception with some limited areas in the mountainous regions where it is slightly above this value (5.37%). In the context of the warmer scenario, the increase in TAO is more differentiated spatially, with higher values (10-16%) in the Danube Delta and in the mountainous regions. In Oltenia, the relative difference is in the order of 6%, lower than in the south-eastern area, for example.

For TMS index, the relative difference between RCP scenarios and the base period indicates also an increase over the entire territory. The increase is small in the colder scenario, ranging between 2 % in north-western part and up to 8% in the highest mountain area and the Danube Delta. In the warmer scenario the same areas present a stronger increase (up to 8% in the Danube Delta and up to 18% in the high mountain areas), while the rest of the territory is characterized by an increase in the range of 4-8%.

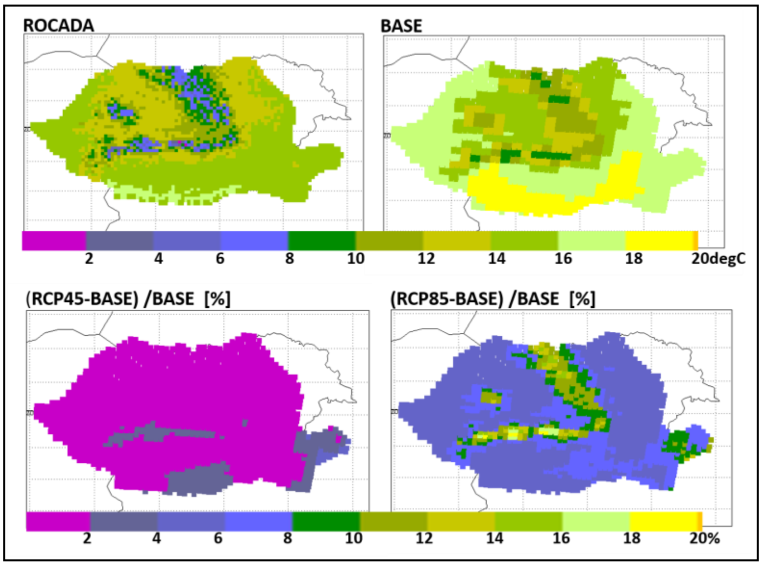

Figure 4. TAO index: Distribution of long-term mean values (1991-2010) from ROCADA (upper left) and model simulation (BASE) (upper right); relative change in TAO index during period 2021-2040, compared to 1991-2010, in the context of RCP45 scenario (lower left) and RCP85 scenario (lower right).

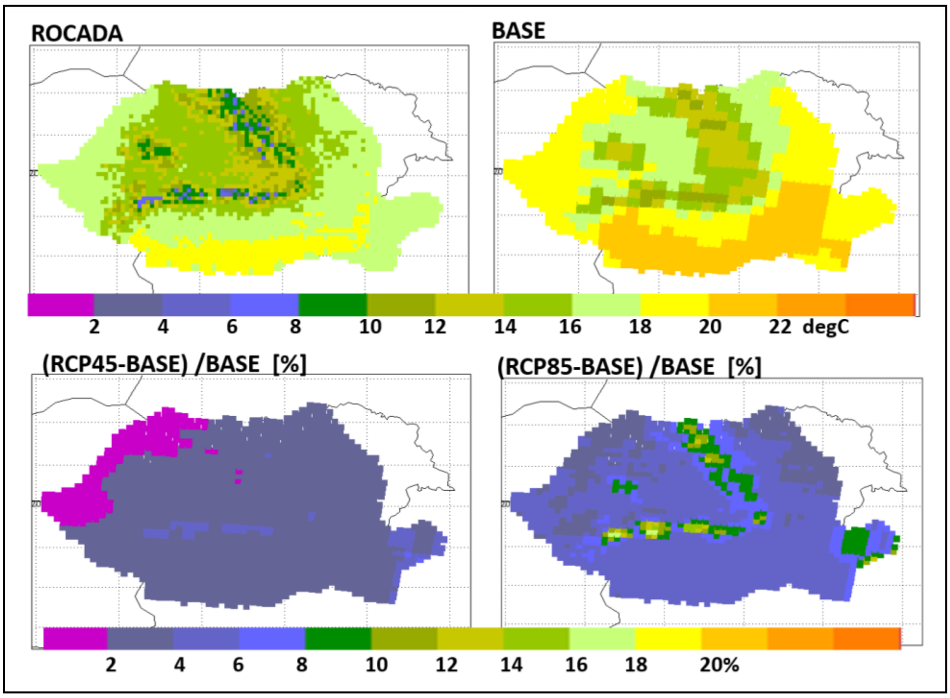

Figure 5. TMS index: Distribution of long-term mean values (1991-2010) from ROCADA (upper left) and model simulation (BASE) (upper right); relative change in TMS index during period 2021-2040, compared to 1991-2010, in the context of RCP45 scenario (lower left) and RCP85 scenario (lower right).

The spatial distribution of long-term mean Winkler index (Fig. 6) derived from the reference data corresponds to the wine growing zones defined at European level (EU, 2013). It indicates the southern areas as favorable for high production of standard to good quality table wines and characterized by WKI index in the range 1600-1800 °C, although the southernmost region, characterized by WKI up to 2000 °C, indicates conditions favorable for high production, but acceptable table wine quality at best. The model simulation for the period 1991-2010 shows even higher values of WKI, especially in the southern region, where it exceeds, on limited areas, 2000 °C. The simulations for the climate projections show that WKI will increase over the entire territory, with 5-10 % in the colder scenario and almost double (10-20%) in the warmer scenario, in both cases the increase being more pronounced in the mountainous regions and in the Danube Delta. Oltenia region is characterized by an increase up to 5% during the colder case and up to 15% in the warmer case.

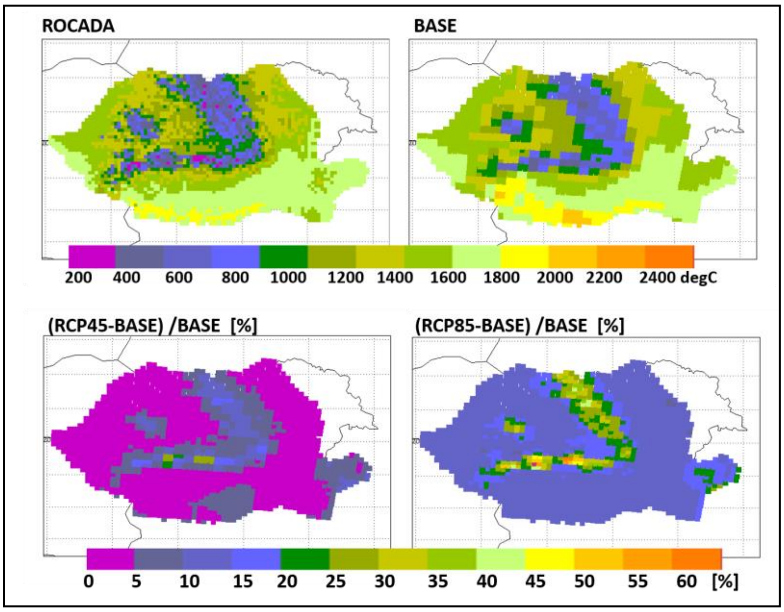

Figure 6. WKI index: Distribution of long-term mean values (1991-2010) from ROCADA (upper left) and model simulation (BASE) (upper right); relative change in WKI index during period 2021-2040, compared to 1991-2010, in the context of RCP45 scenario (lower left) and RCP85 scenario (lower right).

5. CONCLUSIONS

We presented an assessment of physical impacts of climate changes on the thermal conditions quantified with the use of five indices relevant for the agriculture sector, with a focus on Oltenia region. We employ two climate model simulations, corresponding to the coldest and warmest cases among an ensemble of 11 simulations for RCP45 and RCP85 scenarios, performed within EURO-CORDEX experiment.

The results show that model simulations for the base period (1991-2010) reproduce well the spatial pattern of the indices but overestimate their magnitude compared to reference data (ROCADA), more pronounced for the indices implying low/high temperatures (e.g. HD17, WKI). Overall, the results for the reference period show that the indices more focused on the growing season (e.g. GD4, TAO, TMS, WKI) generally present larger values in Oltenia and higher than during the standard climatic period (1981-2010) even in the reference dataset.

The model biases compared to reference data and the uncertainties associated with a specific combination of models are addressed by expressing the future change of the indices as the relative difference between the near-future period (2021-2040) and the base period (1991-2010). The results indicate that in the context of the colder scenario, the changes for all indices are quite small, while for the warmer scenario they may even double in some areas. For HD17 index, the selected climate projection simulations show a decrease of the index values, while all the other indices present positive changes (increase) compared with reference period. The regions with the larger amplitude of changes are mountainous areas and Danube Delta (e.g. for TAO, TMS, WKI). In Oltenia, in the colder case the changes are small – less than 5% for all indices. In the context of the warmer case, in Oltenia the HD17 index may decrease by 12-14% while the other indices may raise by 8-15 %.

The present study, though providing an insight on possible changes in thermal conditions for agriculture, may be further adapted for other threshold values and/or indices relevant for specific cultivated species in order to better document possible adaptation measures in agriculture sector in Oltenia.

While the thermal conditions are very important for agriculture, they represent just one climate factor relevant for this sector. The water availability is also of major interest and it should be investigated in the context of climate changes, in order to provide a more complete image of the physical impacts on the future climate conditions relevant for agriculture. Furthermore, it should be noted that the climate projection simulations available do not take explicitly into account adaptation measures. Possible negative economic impacts in agriculture (e.g. lower productivity and/or yields quality) may be attenuated significantly if proper adaptation measures are implemented.

5. ACKNOWLEDGEMENTS

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