Indecis

Sectorial Climate Services

Integrated approach for the **d**evelopment across **E**urope of user oriented **c**limate **i**ndicators for GFCS high-priority **s**ectors: Agriculture, disaster risk reduction, energy, health, water and tourism

Work Package 6

Deliverable 6.4

Temperature-based climate indicators relevant for agriculture sector in the context of climate changes in Romania

(MeteoRo contribution)

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Abstract: We present an analysis of the physical impacts of climate changes on agriculture with the use of five thermal indices relevant for this sector, targeting the Romanian territory. We consider two climate change scenarios (RCP45 and RCP85) for near-future (2021-2050) and the period toward the end of the century (2071-2100). The climate projection data is provided by bias-adjusted daily mean temperature based on simulations of 5 regional models. The results indicate that the increase in the mean temperature, with the consequence of increasing the available heat load during plants growing time, may have a negative impact on the quality and quantity of agriculture production in some areas, due to less appropriate climate conditions.

Introduction

Agriculture is one of the important economic sectors 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). Taking into account its significant dependence on weather and climate, the long-term planning in this sector may benefit from insights on possible evolutions of specific conditions for specific cultures, based on available climate scenarios.

Previous studies (ORIENTGATE, 2014; Sima et al, 2015; Zhou and Troy, 2018; Şmuleac et al, 2020) showed already increasing trends for some thermal indices relevant for agriculture. For example, (Colan et al, 2019) highlighted that WKI index derived from data during the period 1981-2010 indicates the southern areas as favorable for high production of standard to good quality table wines, being characterized by WKI index in the range 1600-1800 °C, followed by western and eastern regions where early and mid-season table wine varieties are favorized to produce good quality wines. At the same time, in the south-west area the WKI time series shows a quite pronounced increasing trend during the analyzed period, suggesting that the conditions for wine production and quality may change in the context of climate changes. This conclusion may lead to pertinent concerns e.g. will the climate condition in S-SW Romania still be proper for standard to good quality table wines in the future? Which regions may have more potential for producing high/good quality wines e.g. in the next 10-20 years? Similar aspects may appear for other cultivated plants too and indications on the possible evolutions of climate conditions may arise from analysis of climate projections tailored for agriculture sector.

We aim to investigate the physical impact of climate changes in this sector by employing five thermal indices and analyzing their modifications in the context of two climate change scenarios (RCP45 and RCP85), for the time periods (2021-2050 and 2071-2100). The analysis focuses on the entire Romanian territory, highlighting the characteristics of each main agricultural area and modifications of employed indices.

Data and methods

We employ bias-adjusted daily time series of mean temperature from an ensemble of Regional Climate Models (RCMs) from EURO-CORDEX are available from https://data.jrc.ec.europa.eu/dataset/jrc-liscoast-10011. RCMs are used to downscale the results of Global Climate Models from the Coupled Model Intercomparison Project Phase 5. All RCMs are run over the same 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 5 simulations (marked in bold in Table 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 (as possible) 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).

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

No.	**Regional model**	**Driving model**
1	**CCLM-4-8-17**	**CNRM-CEFACS-CNRM-CM5**
		MPI-M-MPI-ESM-LR
		ICHEC-EC-EARTH
2	**DMI_HIRHAM**	**ICHEC-EC-EARTH**
3	**IPSL-INERIS-WRF331F**	**IPSL-IPSL-CM5A-MR**
4	**KNMI-RACMO22E**	**ICHEC-EC-EARTH**
5	**SMHI-RCA4**	CNRM-CEFACS-CNRM-CM5

The analysis makes use of five thermal indices relevant for the agriculture sector, namely:

- HD17 - the heating degree days index (Klein et al, 2009) is defined as the sum of temperatures below 17 degC along a year.
- GD4 - growing degree days (Klein et al, 2009) - represents the sum of temperatures exceeding 4 degC 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 degC during 1 April- 31 October.

The indices are computed for the Romanian territory for each of the RCP45 and RCP85 scenarios, for periods 2021-2050 and 2071-2020.

The spatial distribution of the ensemble-mean values for the historical -type simulations are compared with the spatial distribution of the indices, for the same period (1981-2010), derived from ROCADA dataset (Dumitrescu and Birsan, 2015), as presented in (Colan et al, 2019). This allows the estimation of the ensemble performance compared to reference data and it will help in interpreting the final results.

The analysis focuses on changes of the indices during future periods compared with reference period (1981-2010). The results are presented through maps of HIST simulations, ensemble spread, at country level, for both periods and maps with the spatial distribution of relative change for each index for each scenario and period considered.

Results

The spatial distribution of HD17 long-term mean values over the entire territory from observational based data ROCADA shows the lowest values in the western, southern and south-eastern regions, with HD17 in the range of 2000-2500 degC in the W-SW area and maximum values of 4000-5000 degC (almost 6000 degC on the highest mountain tops) (Colan et al, 2019). The mean of the ensemble models for the HIST period (Fig. 1) presents a very similar spatial pattern, but with slightly different amplitude of the index – larger values in W-SW (about 2500-3000 degC) and lower in the mountains (up to 5500 degC).

The simulations for future periods, in both scenarios, indicate a decreasing trend of the index, quite small in the near-future but more pronounced (up to 20%) in the RCP85 scenario toward the end of the century. In all cases, the most affected regions are the mountainous areas followed by low altitude areas W, SW and E of the country. The ensemble spread is larger in RCP85 scenario, for both periods.

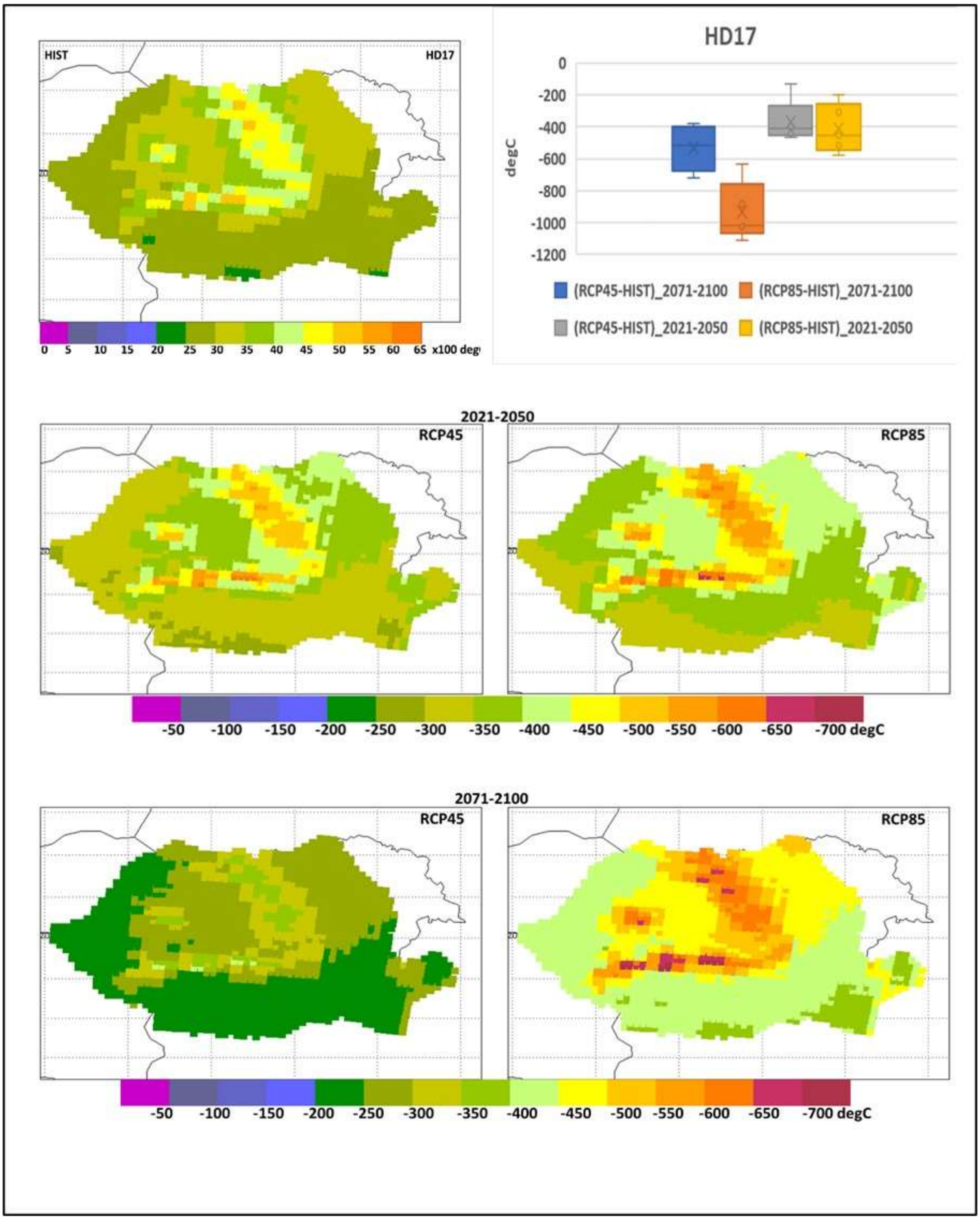

Fig. 1 (From left to right, up-down lines): Spatial distribution of HD17 index for period 1981-2010 (HIST) based on the ensemble of 5 model simulations; ensemble spread for each period and each scenario, as averaged at country level; absolute changes in HD17 index between climate change scenario and HIST simulations, for 2021-2050 and 2071-2100.

For the GD4 index, the spatial distribution in the current climate (1981-2010) based on ROCADA dataset is characterized by largest values in the southernmost areas (3000 degC), followed by values around 2500 degC 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 (1000-1500 degC). The ensemble mean for HIST simulations (Fig.2) indicates higher GD4 values (3500-4000 degC) in the southern areas, while the minimum values in the high areas of the mountains are similar (1000-1500 degC). A significant difference between modelled and observational-based spatial distribution of the index resides in the characteristics of intra-Carpathian region (Transilvania) where the models indicate GD4 values of 3000-3500 degC, while ROCADA dataset indicates up to 2000 degC. These results, together with those for HD17 index, suggest that the ensemble model tends to overestimate the mean temperature.

The modifications in the GD4 values in the context of climate changes are all positive and they present a very well-defined spatial pattern -with higher values in the south and lower values in the north -in both scenarios and periods. In the context of RCP85 scenario, there are more details in the spatial pattern, indicating some limited areas in the western and southern regions with pronounced increase in GD4 (up to 1200 degC). The very eastern area, over the Danube Delta, present the maximum values in all scenarios and periods, but this could be also an effect of models representation of a such a complex terrain as the delta. The models employed in the analysis show a strong agreement, as indicating by the low spread in the ensemble mean at country level.

The growing season temperature index TAO is characterized during 1981-2010, based on ROCADA dataset, by larger values in the south (14-16 degC), followed by western and eastern areas (12-14 degC). The model simulations (fig. 3) show, for the HIST period, a similar pattern but with higher values (about 2 degC) all over the country; furthermore, the S-SW limited area with about 20 degC in HIST is not found in the observational-based data.

The TAO index is expected to increase in all regions of the country, in both scenarios and for both periods. In the near-future (2021-2050), the change is quite small (up to 1.5 degC) and uniformly distributed over the country, in both scenarios. Toward the end of the century, the RCP45 scenario suggests that some limited areas in SW and SE part of the country may experience the maximum increase of TAO (an addition of up to 2 degC), while for the rest of the territory TAO will increase with about 1 degC. However, in the RCP85 scenario, during 2071-2100 TAO may rise with up to 4 degC over almost the entire country, some small areas in the S and SE (Danube Delta) presenting a larger increase (4-6degC). It is worth noting that Danube Delta is again characterized by the largest changes, especially toward the end of the century in the context of RCP45 scenario. This combination in fact (RCP85 scenario + period 2071-2100) presents the largest uncertainty, as shown by the ensemble spread averaged over the entire country.

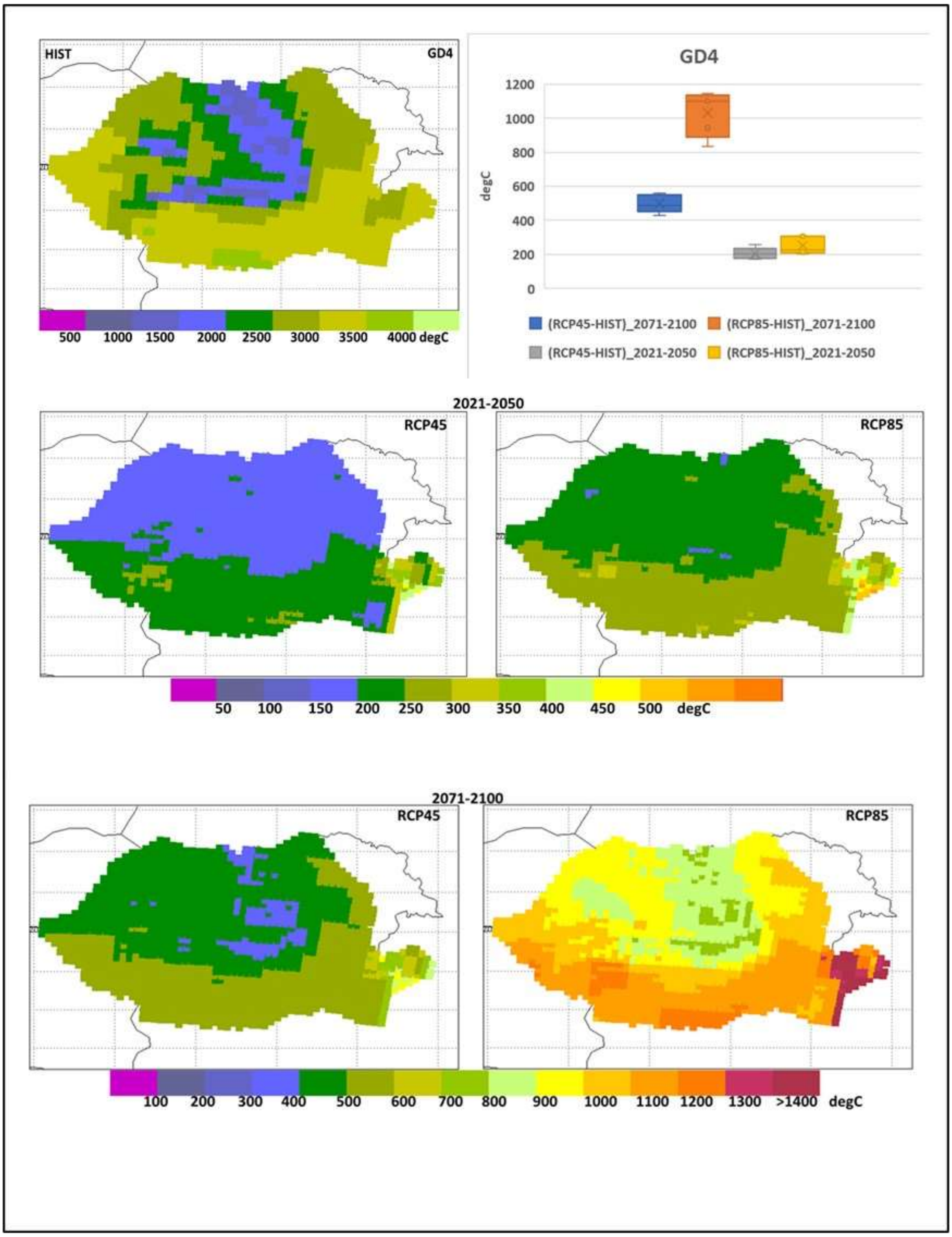

Fig. 2 (From left to right, up-down lines): Spatial distribution of GD4 index for period 1981-2010 (HIST) based on the ensemble of 5 model simulations; ensemble spread for each period and each scenario, as averaged at country level; absolute changes in GD4 index between climate change scenario and HIST simulations, for 2021-2050 and 2071-2100.

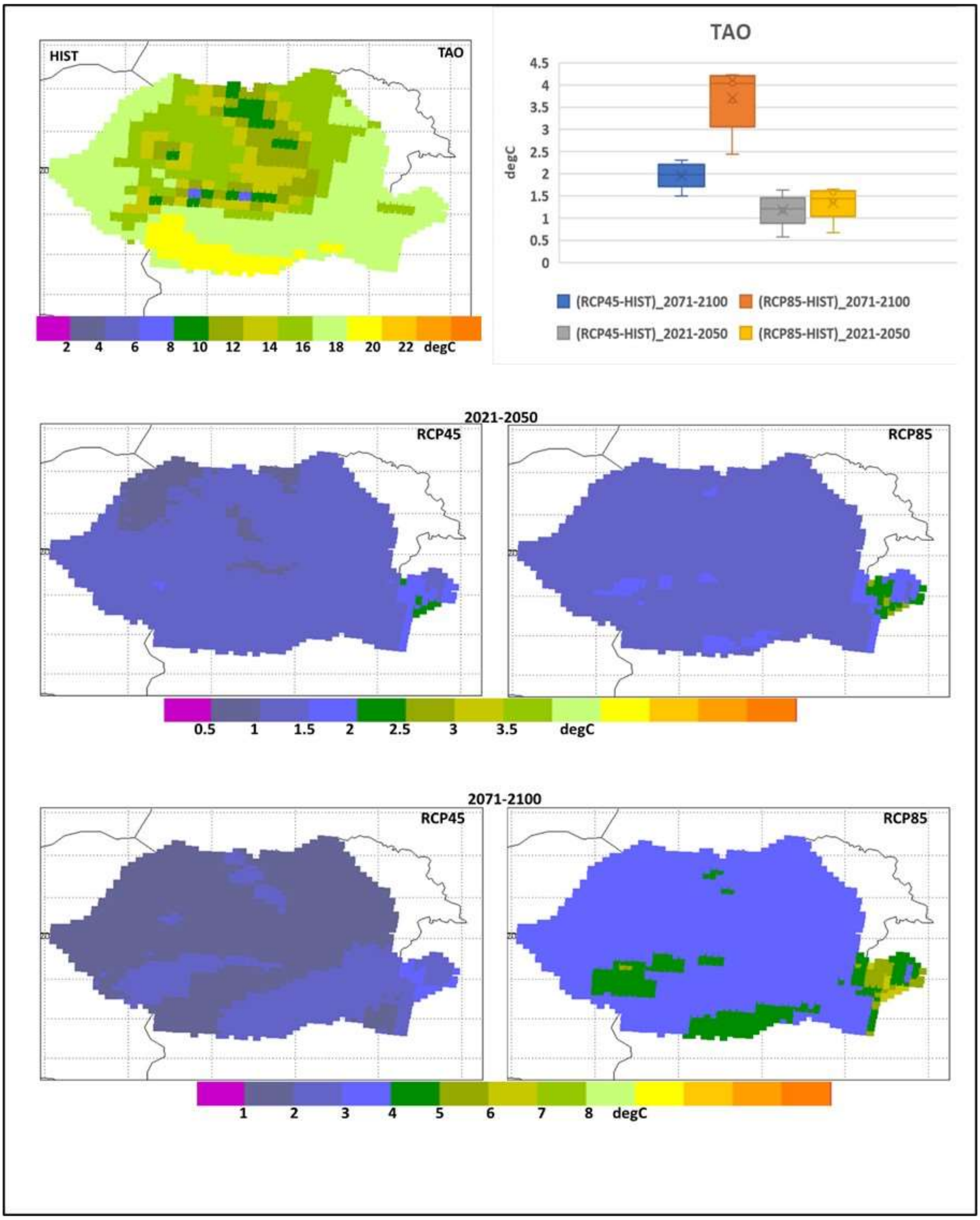

Fig. 3 (From left to right, up-down lines): Spatial distribution of TAO index for period 1981-2010 (HIST) based on the ensemble of 5 model simulations; ensemble spread for each period and each scenario, as averaged at country level; absolute changes in TAO index between climate change scenario and HIST simulations, for 2021-2050 and 2071-2100.

The TMS index presents a similar spatial distribution for historical period (1981-2010) as TAO, but with larger values, as expected. Compared to ROCADA dataset, the models (Fig 4) indicate higher TMS values, with about 2 degC more in the southern regions and up to 4 degC larger in the mountains, supporting the idea that the models overestimate the mean temperature, possibly more pronounced in the high topography areas.

The changes of TMS for the near-future period are positive in both scenarios, the increase being in the range 1-1.5 degC for the entire territory with the exception of two limited areas in the south, where the increase reaches 2 degC and, again, the Daube Delta, where TMS may increase with up to 3 degC. Toward the end of the century, the spatial distribution of differences in TMS compared with HIST period presents three well-defined regions -the southern area, characterized by a strong increase if about 5 degC, the norther area – with a TMS increase of 3-4 degC and the Danube Delta, where TMS may rise with up to 7 degC. However, this combination is also characterized – juts like for TAO- by the largest uncertainty (i.e. largest ensemble spread).

The spatial distribution of long-term mean Winkler index derived from ROCADA 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 degC), followed by western and eastern regions where early and mid-season table wine varieties are favorized to produce good quality wines (WKI in the range 1200-1600 degC). The model simulations show, for the same period (Fig 5) larger values (with 200-400 degC) in the south; for the rest of the country, although the modelled values are on average with up to 200 degC larger than those based on ROCADA, the spatial distribution pattern is similar with the observational-based climatology.

In the near future, in both scenarios an increase in WKI of about 200-250 degC in the southern region and 150-200 degC in the western and eastern regions may be expected from the ensemble model employed. Even taking into account the models overestimation for the HIST period, this increase may lead to less favourable conditions for vineyards in the south of the country, while the rest of the wine regions may experience still appropriate climate conditions for this agricultural branch. Toward the end of the century, the amplitude of the increase in WKI almost doubles in the context of RCP45 scenario, while in the RCP85 scenarios it may rise up to 4 times compared to 2021-2050 in the southern region (up to 900 degC). The easternmost area, which includes Danube Delta, is characterized again by the largest increase, reaching 1400 degC. Nevertheless, this combination of scenario and period presents, again, the largest uncertainty.

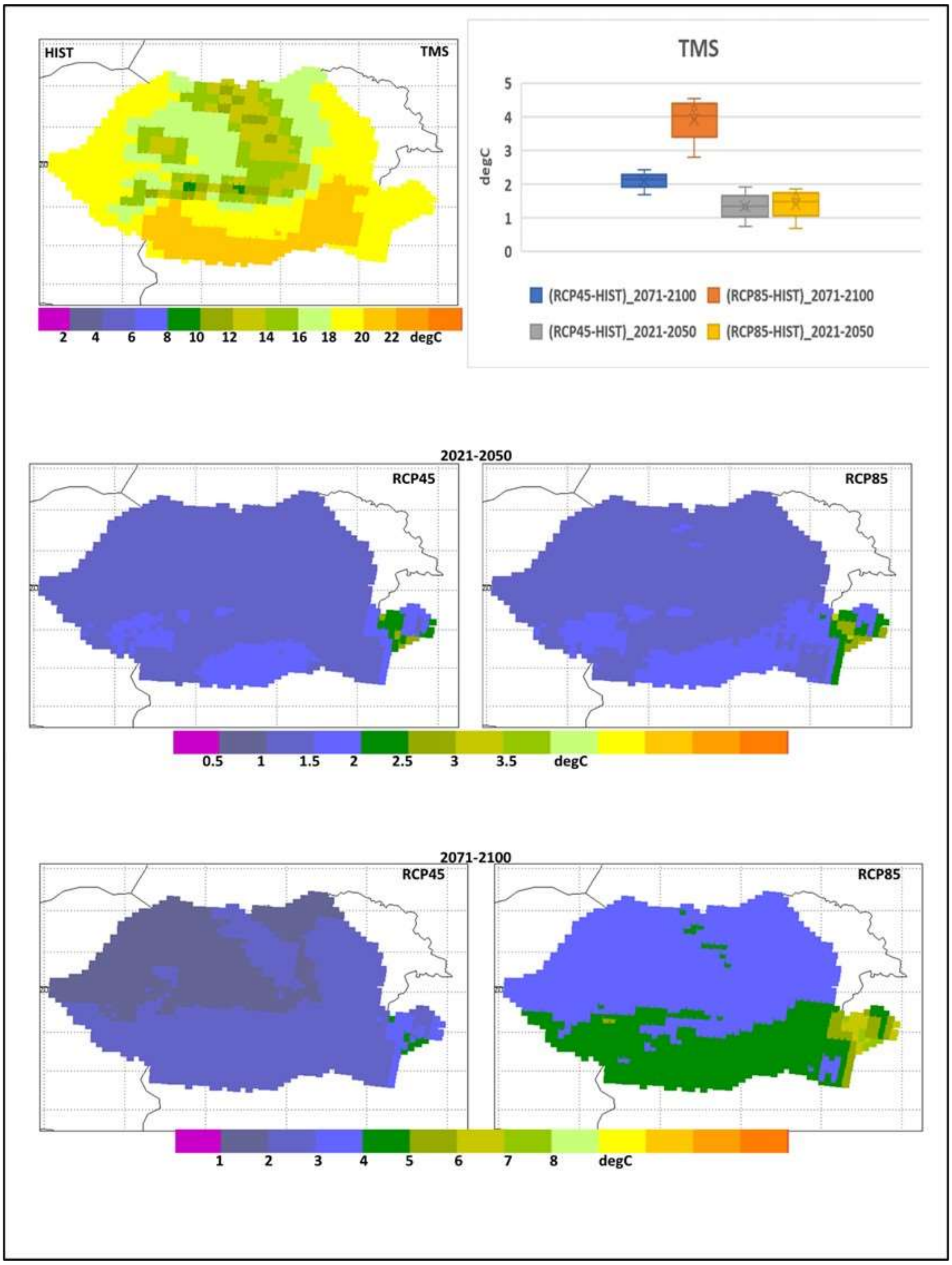

Fig. 4 (From left to right, up-down lines): Spatial distribution of TMS index for period 1981-2010 (HIST) based on the ensemble of 5 model simulations; ensemble spread for each period and each scenario, as averaged at country level; absolute changes in TMS index between climate change scenario and HIST simulations, for 2021-2050 and 2071-2100.

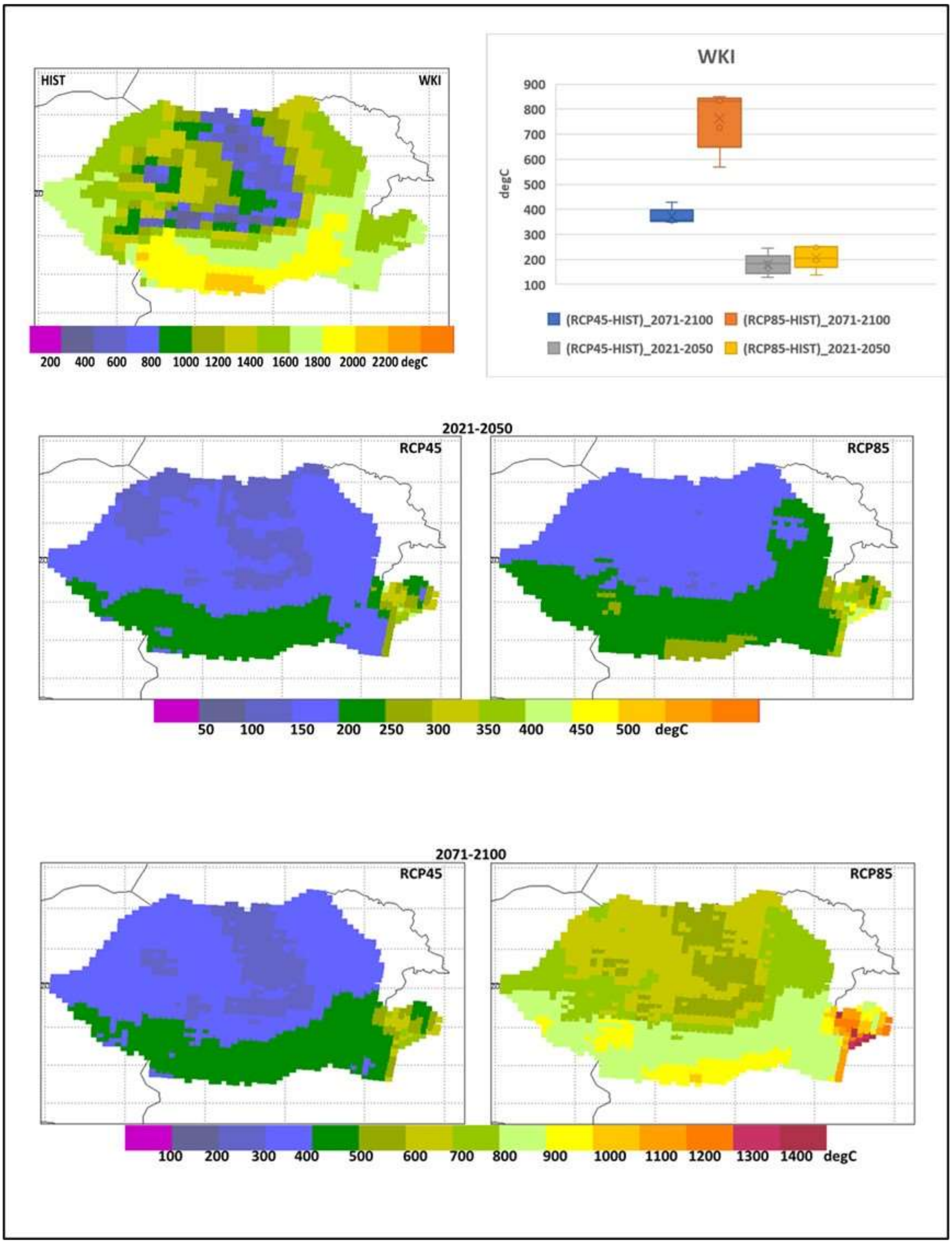

Fig. 5 (From left to right, up-down lines): Spatial distribution of WKI index for period 1981-2010 (HIST) based on the ensemble of 5 model simulations; ensemble spread for each period and each scenario, as averaged at country level; absolute changes in WKI index between climate change scenario and HIST simulations, for 2021-2050 and 2071-2100.

Discussions

The modifications in the indices values and spatial distribution express aspects of the physical impact of climate changes and they may be useful to characterize the favorability of climate conditions for certain branches in agriculture. The indices employed in this study refer only to thermal feature of the climate and thus they cannot be used alone to derive sound conclusions on possible new opportunities or drawbacks associated with the climate changes, although they still may provide some insights.

A correlation analysis between the agricultural production and the indices employed in this study for the period 1990-2010 for Dolj county (Fig. 6) supports the idea that thermal facet of the climate is only one of the components needed for agriculture.

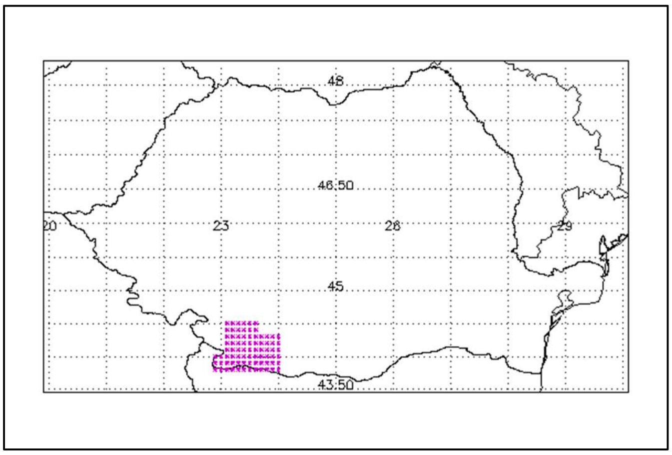

Fig. 6 Location of Dolj county, highlighted through gridpoints of ROCADA dataset.

The analysis made use of indices computed from ROCADA and averaged over the Dolj county area as well as sectoral data from the database of the National Institute for Statistics at the county level, for potatoes, melons and pepper crops– three important types of cultivated plants found in Dolj county. The largest correlations were found in relation to GD4, in particular for early potatoes (0.453) while correlations with TAO and TMS were slightly lower (Table 2). However, the results confirm that temperature-based information alone cannot explain the year-to-year variability for these crops. The analysis is limited by several important factors, in both data sets used – for example in the climate data due to the annual average of the indices and for not taking into account the relation with the vegetation cycle and in the sectoral data, due to the inherent limitations of data collecting process (i.e. self-reporting for agriculture companies and interview-based for other agricultural units).

Table 2. Correlations between the annual yields for three types of crops found in Dolj county and thermal indices used in this study, for period 1990-2010.

Culture/thermal index	GD4	TAO	TMS
Early potatoes	0.453	0.425	0.434
Melons	0.388	0.348	0.385
pepper	0.326	0.397	0.346

Nevertheless, the results may still offer some insights on the potential changes in the quality or quantity of the yields for these crops. For example, taking into account that for the potato crop an optimal accumulated temperature is in the range 1250-2200 degC (at a threshold of 5 degC) (Haverkort et al., 2004) and that in Dolj county the GD4 index is expected to rise by 8-10% in the near future and by 16-30% toward the end of the century compared to current conditions, it may be anticipated that the climate conditions may become less suitable for this crop in the region analyzed. This is line with the conclusions of one of the first studies on the effects of climate change on the potato crop (Hijmans et al. 2003). The sudy used 1960−1990 meteorological data and anlaysis of the future climate refered to period 2040−2069. The authors assumed an increase of average global temperature of 2.1 °C and 3.2 °C depending on the climate scenario. In these conditions, the study showed that the total global yield in the regions currently cropped with potato may decline by 18, respectively, 32% with unaltered planting time and varieties and between 9-18% if planting time and varieties were adapted to the new conditions. Thus, the drawbacks associated with the climate changes may be, at least to some degree, be attenuated by efficient adaptation measures.

The same is valid for other crops, like for grapes and, implicitly, wine. Mozell and Thach (2014) showed that despite the fact that increasing temperatures will lead to significant changes in the geographical location of grapes cultivated areal (e.g. northward shifting) and even in the fruits characteristics (e.g. elevated fruit sugar, lower acid concentrations) there might be some practical solution to limit the negative impacts. For Romania, in the south-western region the expected changes in WKI are in the order of 11% in the near future and between 25-50% toward the end of the century compared to the current (1981-2010) climate conditions. These changes may lead to unsuitable conditions for current grape varieties, but with adequate adaptation measures, including change of cultivated plants, the agriculture activities in this region will still be profitable.

Conclusions

We investigate the physical impact of climate changes in the agriculture sector, with a focus on Romanian territory. To this end, we employ five indices (HD17, GD4, TAO, TMS, WKI) relevant for this sector and included in the INDECIS indicators database. The amplitude and spatial distribution of changes in the indices is analyzed in the context of RCP45 and RCP85 climate change scenarios, for periods 2021-2050 and 2071-2100, using bias-adjusted data of daily mean temperature.

The results show that all indices except for HD17 present an increasing trend in both scenarios and for both periods analyzed. The HD17 index, being related to the low temperatures, present a decreasing trend. The amplitude of the change, for all indices, is more pronounced toward the end of the century and in the context of RCP85 scenario, but this is also associated with the largest uncertainty as expressed by the ensemble spread averaged over the entire territory. The regions expected to experience the largest changes are the southern part of the country, the mountain areas as well as the easternmost region including the Danube Delta. The comparison between models simulations of the current climate (1981-2010) and the one derived from observation-based data (ROCADA) suggest that the models overestimate the mean temperature, possibly more pronounced in the high topography areas. Also, the area including the Danube Delta is characterized by the largest increase for all indices, possibly due to the limitations of models in representing such a complex area as that of a delta.

The changes in the indices analyzed may provide useful information on the suitability of climate conditions for agriculture in the context of climate changes. For example, the GD4 index may be related to the conditions required by the potato crops and its expected increase, especially toward the end of the century in the context of RCP85 scenario, suggests that the yields for potato crops may decrease in the new conditions, particularly if no adaptation measures are put in place. Similarly, the increase of up to 50% in WKI index in south-western part of the country, toward the end of the century in the RC85 scenario, may lead to unsuitable conditions for the current grape types cultivated in this area.

However, the thermal indices employed in this study cannot give, alone, a fully comprehensive picture of future needs for agriculture and more in-depth studies of change in the climate conditions, adapted for specific crops, should be used for defining specialized and efficient adaptation measures.

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